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Publications of the Disaster Prevention Research Institute

The Disaster Prevention Research Institute has published the achievements of its research activities in two kinds of publications, namely "Annuals (in Japanese)" and "Bulletins", Bulletins having been monographs published on occasion. Annuals will continue to be published in the same style as before. Bulletin, however, has been changed into a new style with the title of "Bulletin of the Disaster Prevention Research Institute" from Volume 14. Bulletins already published are listed on the end of this publication.

One volume of the new style Bulletin is divided into four Parts published quarterly in one academic year. Part 4 of each volume includes only the abstracts published by staffs of this institute in the year.

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On the Application of Seismic Prospecting in Engineering Projects

By Dr. Sci. Sōji Yoshikawa and Chōrō Kitsunezaki

Annuals, Disaster Prevention Research Insititute, Kyoto University,
No. 7, 1964, pp. 39-49.

Abstract

Recently, seismic prospecting has been conducted for many engineering projects, the results obtained, however, are limited in their applicability for engineering purpose, because geological structure and physical property are given only in relation to the velocity contrast of the longitudinal wave.

To overcome this difficulty, the more general characteristics of seismic waves should be considered, besides the velocity of the P-wave. In view of the above, some results of investigations of seismic prospecting, in the case of tunnels and dam sites, are developed in this paper.

The main results are as follows:

1. The propagating velocity of the trasversal wave and its attenuation factor give accurate information regarding the geological condition of the foundation. In some cases, the geological structure obtained from the analysis of the S-wave does not always coincide with that of the P-wave:

When soil pressure is remarkably high, the ground structure and the corresponding velocity of elastic waves shows complicated values and the velocity values indicate different physical properties from the original constituting material.

2. The mode of the vibration (i.e., the duration time, periods and the decay of the waves) conveys the geological structure and the rock property of the place in some cases.

3. The method of seismic prospecting had been generally conducted from the ground surface.

The existence of weathered layer, however, obstructed the analysis of the results. By changing the lay out of pick-up position (i.e. by putting the pick-ups in drifts and bore holes a better geological structure will be obtained.

On the Refraction of a Cylindrical Pulse in an Infinite Elastic Medium with a Single Rigid Layer

By Michiyasu Shima

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 83-94.

Abstract

The present paper deals with the elastic SV wave refracted through a single layer, when a semi-infinite elastic medium is excited by a buried impulsive line SV source. The effects of the thin layer on the propagation of elastic

waves are extremely complex. Therefore, the seismogram cannot be interpreted exactly from the viewpoint of the geometrical optics, particularly when the distances of the source and the observation point from the thin layer are considerably shorter than that of the observation point from the source. According to L. Cagniard, the integral transformation method is used to obtain an exact closed expression for the displacement of the refracted wave through the thin layer as a function of time.

The impulsive line SV source is the Dirac's delta function of time. The displacements were computed as a function of time for the ratio=2 of the velocity of the thin layer to that of the neighboring media. Except directions corresponding to small incident angles, there appear two different groups of the SV type. The phases of the first group appear at $t=t_{on}$ and satisfy minimum time criteria. They can be explained by the geometrical method. The displacements and the derivatives of the displacements with respect to time are infinite at $t=t_{on}$. The phase of the second group, which appears later than the first, is not deducible by the geometrical method and is not well defined at the arrival time. It gradually increases and decreases. Thus, the apparent period is much longer than the first. The phase of the second group gains in dominance with the decrease of the thickness of the thin layer and vanishes gradually as it moves to infinity. Therefore, this phase may be a kind of diffraction effect due to the interaction between the two boundary planes of the thin layer. Thus for the same value of h, the amplitude of the second phase increases with the rise of H and at the high value of H decreases a little. This phase is masked by the tail of the phase of the first group and thus is not well defined. The difference of the arrival time between the two phases and the apparent period of the second become smaller with the increase of H.

On the Diffraction of Elastic Plane Pulses by the Crack of a Half Plane (Three Dimensional Problem)

By Michiyasu SHIMA

Bulletin, Disaster Prevention Research Institute, Kyoto University, No. 64, 1964, pp. 1-20.

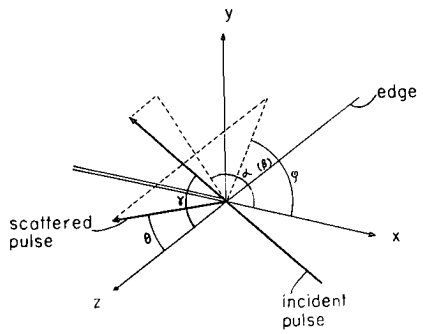
Abstract

In the previous paper, the writer investigated the two dimensional problem of the diffraction of plane elastic P and S pulses by a crack of the half plane ; the plane of incidence of the pulses is perpendicular to the edge and the stress is equal to zero on such a half plane. In this paper, the three dimensional diffraction by the crack of the half plane, which is a free surface, is treated by D. S. Jones's method in the diffraction of a scalar wave. That is, firstly the formal solutions for the harmonic wave are obtained by his method, then, taking the inverse integral transformation, the solutions are calculated for the incidence of the plane pulses of a rectangular type.

In our numerical examples, we assumed

$$K=\sqrt{11/3}k, \qquad \alpha=30°, \qquad \gamma=60°$$

We investigated the diffraction picture resulting from the incidence of the plane longitudinal pulse, where the front of the incident pulse is always a plane intersecting the z-axis at the point $z=\frac{t}{c}$ This point is a vertex of the cone occupied by the diffracted pulse. We calculated the azimuthal distribution of the displacement of the diffracted pulse, which is the second and third term in the equation, at $\sqrt{\frac{a\varepsilon}{r}}=0.1$ and $t=\frac{r}{a}+\varepsilon$ for the diffracted P pulse or $t=\frac{r}{b}+\varepsilon$ for for the diffracted S pulse.



The φ-dependence of the displacements of the diffracted pulse for $\theta=$constant is quite similar to that of the amplitude in the case of the incidence perpendicular to the edge of the plane P pulse. That is, the amplitude of the diffracted P pulse increases at a uniform rate with the approach of φ to $\pm 30°$ and the phase is reversed at the shadow boundary of the incident P pulse and the reflected P pulse; the displacements are a kind of double jerk. However, the composite displacement of this pulse with the reflected P pulse for $\varphi<0$ or the incident pulse for $\varphi>0$ is continuous at the boundary. With the diffracted S pulse, meanwhile, the displacement varies continuously and becomes zero at $\phi=63°7'$ for $\phi>0$. The phase is reversed at the boundary $\varphi=-63°7'$ for $\varphi<0$ and the composite displacement with the reflected S pulse is continuous at this angle.

Source-Mechanism of the Chilean Earthquake from Spectra of Long-Period Surface Waves

By Tatsuhiko WADA, Tamotsu FURUZAWA and Hiroyasu ONO

Bulletin of the Seismological Society of Japan, Vol. 16, No. 4, Jan. 1964, pp. 50–60.

Abstract

The great Chilean Earthquake of May 22, 1960, gave many important informations for seismology. The long-period surface waves from this earthquake were also obtained from the Galitzin type seismographs at Abuyama Seismological Observatory of Kyoto University. The analysis of seismograms of the great Chilean Earthquake have given the results for free oscillations of the earth and for the phase and group velocities of long-period surface waves.

Press, Ben-Menahem and Toksöz (1961) gave some preliminaly results of determining fault parameters of earthquake focus, namely fault length and rupture velocity, from analysis of long-period surface waves. This study

was also made using the Mongolian Earthquake of December 4, 1957, by Ben-Menaham and Toksöz (1962). The theoretical bases for this method have been described by Ben-Menahem (1961). He defined the directivity function under the basic assumption that the faulting process may be represented by a moving source. That function is equal to the ratio of spectral amplitudes of waves leaving the source in opposite directions and depends upon the fault length, the rupture velocity and the direction of the fault. This method is independent of the instrumental character, since we can use even- and odd-order surface waves recorded at the same station.

It this paper we made analysis of only R_3- and R_4-trains of the seismograms recorded at Abuyama Seismological Observatory. According to the results of Press et al. (1961), the Abuyama station is located near the nodal lines of radiation pattern. Furthermore, the traveling distances of waves leaving the source in opposite directions is not very different each other, and so R_3- and R_4-trains cannot be separated perfectly. Thus we were interested in examining whether it is possible to determine the fault parameter using directivity function even under such unfavorable conditions.

Long-period Rayleigh waves R_3 and R_4 were read, digitized at 3/2-sec intervals, filtered with a 39-coefficient triangular lowpass digital filter, and Fourier-analyzed using the Filon's method. The fault parameters we obtained were a fault of 1200 km, with an azimuth of W80°S, and a rupture velocity of 3.5 km/sec. These results gave the best fit to the results obtained by Press and others.

On the Short Period Volcanic Micro-Tremore at Mt. Aso

By Shigetomi KIKUCHI

Bulletin of the Volcanological Society of Japan, Vol. 9, No. 1, August, 1964, pp. 9-16.

Abstract

The author has observed the short period micro-tremors near the crater since 1959. He obtained the following results about them.

1) The micro-tremors have different predominant periods in each time of the volcanic activity. The difference seems to be due to the depth of the origin of micro-tremors.

2) The predominant period of micro-tremors which are oscillating on a vertical plane in a direction to the crater is different from that of micro-tremors oscillating on a perpendicular plane at right angle to the crater. Taking consideration of the difference of the predominant period, modes of oscillation and velocities of propagation, the former seems to be a kind of Rayleigh wave and the latter a kind of Love wave.

3) The micro-tremors are propagating from the crater at the velocities from 600 m/sec. to 1500 m/sec.. Micro-tremors in a wave train are transmitted from nearly the same direction. And they present phenomena like dispresions of surface wave.

4) There are good correspondences between the micro-tremors and the micro-earthquakes origination near the crater. The micro-tremors seem to be Rayleigh and Love waves generated by the micro-earthquakes near the crater.

He found the phenomena like dispersion of surface waves in the observation of micro-tremors carried out in December 1961. In this paper he tried whether or not we could explain the phenomena as dispersions of surface waves. Based on the underground structure determined by means of seismic exploration, various dispersion curves of surface waves with single or double superficial layer were drawn. In case of $H_1=17.1$ m, $H_2=40.0$ m, $V_{P1}=1500$ m/sec., $V_{P2}=2100$ m/sec., $V_{S1}=235$ m/sec., $V_{S2}=839$ m/sec., $V_{S3}=1030$ m/sec., $\mu_2/\mu_1=20.0$, $\mu_3/\mu_2=1.60$, dispersion curves of surface waves well conform to the velocity-period relations of micro-tremors.

On Anomalous Crustal Deformation Observed before Some Recent Earthquakes (Part II)

By Eiichi NISHIMURA and Yutaka TANAKA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, 1964, pp. 66-75.

Abstract

Observational results of crustal deformation in the later major earthquakes (the Shirahama-Oki on Jan. 4, 1962, M=6.4 and the Echizenmisaki-Oki on Mar. 27, 1963, M=6.9) were reported.

(1) According to the results of strain observation, the ground always extends in the N-S direction and contracts in the E-W direction at Yura just after the occurrence of medium earthquakes in Kinan District, and the amount of extension is also always larger than that of contraction. Only in the case of the Shirahama-Oki Earthquake did the ground extend in the E-W direction and contract in the N-S direction, but strain was larger in the N-S direction as usual.

These results may be explained by the following: Almost all earthquakes in Kinan District are of the quadrant type, and, in the N-S direction, they have maximum tension when originating within the northern upper side of the plane inclining northward, and maximum pressure within the southern lower side. The effects on crustal deformation at Yura, however, are the same as extension in the N-S direction in both cases, excepting the Shirahama-Oki Earthquake. This coincides with the fact that the southward horizontal displacements in this region are relatively large in the southern part, namely extending in the N-S direction.

It may be inferred from the above evidence that the ground in Yura and its neighbourhood repeats the same behaviour every time medium earthquakes occur, but, sometimes, when major earthquakes with maximum tension in the N-S direction occur in the southern lower side, a reactive effect is added to the ground.

(2) Anomalous ground tiltings accompanying the Echizenmisaki-Oki Earthquake were observed at Ogoya, Kamioka and Ikuno. These are divided into three stages judged from the manner of tilt variation.

If one accepts that this earthquake belongs in the Kitamino Earthquake Sequence (shown by similarities in the nature of occurrence and the mode of crustal deformation) the stages of anomalous tilting may be systematized as follows: the first stage is part of the stepwise motion proper to the Sequence in the direction of horizontal displacement; in the second stage, the ground tilts toward or opposite the epicenter, and, in the third stage, the movements of the second stage increase rapidly or are reversed. It seems that these are the respective reflections of accumulation, concentration and release-beginning of strain energy.

On the Relation between the Activity of Earthquakes and the Crustal Deformation in Yoshino Distrist

By Eiichi NISHIMURA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 14, Part 1, August, 1964, pp. 1-7.

Abstract

Some examples of the anomalous tilting of the ground were already reported by this author in the cases of earthquakes at Tottori, Daishôji-oki, Hyûganada, Kitamino, and so on. In the case of these earthquakes, it was observed that the anomalous ground tilting proceeded generally through several stages. But it remained uncertain when the anomalous tilting commenced and when it ceased, presenting an important problem, "anomalous" tilting. In this paper, the relation between the activity of a series of earthquakes and the anomalous ground tilting is reported in some detail.

In Yoshino District in the Kii Peninsula there occurred a large earthquake, the so-called Yoshino earthquake, magnitude 7.0 at a depth of 70 km (July 18, 1952). During the four succeeding years, there occurred another seven earthquakes, at a depth of from 60 km to 70 km, in this district. Examining the ground tilting in these earthquakes, it was found that the manner of ground tilting before and after earthquakes was common to all, namely the tilting speed suddenly changed after the earthquake and continued till the next earthquake. Another noticeable characteristic of these earthquakes was that the anomalous ground tilting was found in a specific direction, rather than on the radial or transversal direction to the epicenter.

In view of the "push" and "pull" distribution in the initial ground motion, all these earthquakes belong to the cone rather than the quadrant type. Further, the cone axes of these earthquakes substantially coincide with each other in their direction. Since these eight earthquakes had the same push-pull distribution and the same manner of ground tilting, it was concluded that they might have been caused by the same earthquake-generating force.

It is also noteworthy that the direction of the above-mentioned cone axes coincides with that of the distribution of epicenters, as well as with an anticline axis in the neo-tectonic movement in the Kii Peninsula. From these observations, it was concluded that all these earthquakes were caused by the same earthquake-generating force, possibly an intrusive force due to magmatic intrusion.

Study on the Relation between Local Earthquakes and Minute Ground Deformation at Wakayama (Part 3)

By Torao TANAKA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, 1964, pp. 61–65.

Abstract

In this paper, an example of the application of a filtering method for the detection of ground deformation caused by earthquakes is reported. Observation of crustal deformation with tiltmeters or extensometers is generally disturbed, to a great extent, by the change of atmospheric pressure and temperature, rainfall, underground water, deformation near the observation room and so on. It is easy to identify the characteristic crustal deformation of earthquake when the amount of deformation is larger than that of the above-mentioned disturbances. But it is very difficult when the deformation caused by earthquakes is in the same order, or less, than the above disturbances.

In this case, some kind of reduction is required, and two methods seem to be effective. On is the elimination method, based on determining the amount of ground deformation due to each disturbing factor; this should then be subtracted from the observed ground deformation. The other method is the filtering system. Defining the crustal deformation of an earthquake as a signal and all other deformations as noise, the filtering method means the application of a suitable filter to a time series containing noise. Because of the lack of knowledge about the form of such signals, we must apply band-pass filters with different responses.

We made four low-pass filters with a frequency response of $R(f)=\exp(-2\pi^2 f^2)$, one high-pass filter with a response of $R(f)=1-\exp(-2\pi^2 f^2)$ and two band-pass filters obtained by the combination of two low-pass filters. We applied these filters to analyse the data obtained by the tiltmeter (horizontal pendulum type) at Wakayama City. Results showed that, if there occurred crustal deformation with the period of two or several hours of an earthquake it could be effectively detected in this way. This method, therefore, is considered to be a useful system for investigating the relation between minute crustal deformation and earthquakes.

Study on the Relation between Local Earthquakes and Minute Ground Deformation

Part 1. On Some Statistical Results from Local Earthquakes Occurred in the Wakayama District

By Torao TANAKA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 14, Part 1, August, 1964, pp. 55–77.

Abstract

Observations on ground deformation and local earthquakes were carried out at Wakayama City, where small earthquakes occurred very frequently. The P–S time distribution of local earthquakes recorded at Oura (34°11′16″N, 135°09′30″E) showed a peak between 0.9 and 1.0 sec. The coefficient of Ishimoto-Iida's formula was estimated as about 1.9. The periodicity of local earthquakes was investigated, and the periods of solar 24 and 2.4 hour and lunar 24 and 3.4 hour seemed to predominate. As for the time interval distribution of the earthquakes, it could not be determined which was the more suitable form of frequency distribution, $f(\tau)d\tau = be^{-\lambda\tau}d\tau$ or $f(\tau)d\tau = k\tau^{-p}d\tau$. Ground deformations were observed at Oura and Akibasan (34°11′48″N, 135°10′23″E) with tiltmeters and extensometers. Ground deformations due to oceanic tidal changes and meteorological effects were considerable at both stations. The elimination of these disturbances was required to investigate the crustal deformation caused by local earthquakes. Assuming that ground deformation recorded by tiltmeters or extensometers can be represented by the linear combination of each disturbing factor, the coefficients of the ground deformations to the factors may be calculated by the method of undetermined multiplier (when all factors are known). The practical procedure for obtaining the coefficients is as follows: The mean daily variations of ground tilting and strain were obtained from one month's observational data. Then the mean daily variation of the oceanic tidal height at Wakayama Harbour was subtracted from the mean daily variation of the ground tilting and strain, when the amplitude and phase of the oceanic tide were corrected by the ratio and the phase difference, calculated from the result of the harmonic analysis of the M_2 component. We calculated the disturbing coefficients from the residual by the method of least square. Disturbances of atmospheric pressure, its time gradient and atmospheric temperature were accepted as disturbing factors. Using these coefficients, disturbances were subtracted from the original data, before and after the three remarkable local earthquakes. We cannot, however, conclude whether any peculiar crustal deformation is connected with these local earthquakes or not, because of the insufficient reduction of obstructive disturbances.

Determination of Local Phase Velocity by Intercomparison of Seismograms from Strain and Pendulum Instruments

By Takeshi MIKUMO and Keiiti AKI

Journal of Geophysical Research, Vol. 69, No. 4, 1964, pp. 721–731.

Abstract

An attempt has been made to determine the local phase velocity of seismic waves by a combined analysis of records obtained by strain and pendulum seismographs.

The record of a strain seismograph may be reducible to the space derivative of the ground displacement with respect to the direction of a strain rod, whereas the time derivative of the same displacement may be obtained from a pendulum record. The ratio of the two derivatives should then give the apparent local phase velocity of the waves along the direction of the instruments. The true phase velocity and direction of approach (of any type of seismic waves) could therefore be determined from the amplitudes, instead of time delays in the conventional method. These would be recorded by two horizontal components of the respective seismographs set up at a single station.

In order to get the velocity of seismic waves from actual seismograms, an amplitude and phase equalization technique was applied to the two kinds of seismograms over an appropriate frequency range. The phase velocity can be obtained by

$$\frac{c(\tau)}{\cos\alpha}=\frac{Ks}{K_p}\cdot\frac{\int r_p(t)f_p(t+\tau)dt}{\int r_s(t)f_s(t+\tau)dt}$$

where α is the direction of wave approach, K_p and Ks are the instrumental constants of the pendulum and strain seismographs, and $f_p(t)$ and $f_s(t)$ are the seismograms recorded by the two kinds of seismographs respectively. $r_p(t)$ and $r_s(t)$ are the equalization functions which restore the ground displacement by compensating the distortion that is introduced by the instruments.

The results obtained by the present method, which was applied to five distant earthquakes recorded with Benioff type seismographs at Pasadena, California, agreed with the theoretically predicted velocity for body waves, and in some cases for surface waves. The values obtained, however, are not always consistent with the velocities from conventional tripartite station arrays. This suggests that the former show localized velocities, while the latter represent the values averaged over a certain area. The present technique may be useful for the identification of various phases, especially of body waves and higher mode surface waves, over an entire seismogram.

This work was done during the authors' stay at the Seismological Laboratory, California Institute of Technology at Pasadena, California, U.S.A..

Investigation on the Origin Mechanism of Earthquakes by the Fourier Analysis of Seismic Body Waves (I)

By Yoshimichi KISHIMOTO

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
No. 67, March, 1964, pp. 1-37.

Abstract

The P waves of forty earthquakes of various magnitudes, and focal depths in various regions, were subjected to Fourier analysis for the purpose of investigating the origin mechanism.

First, the changes of spectrum with the epicentral distance, the azimuth and the location of observation station, were examined. The spectrum of P wave does not seem to change greatly with epicentral distance, at least between 30° and 90° and in a wave-period range of 4 to 60 sec. The azimuthal change of spectrum of P wave does not seem to be remarkable in some earthquakes, but it does in others. It is considered necessary to examine this problem in some detail. There are some characteristics of Pwave spectrum which depend on respective stations.

It is possible (based on the phase spectrum) to classify most earthquakes into two groups. It was made clear that the earthquakes in one group have impulsive wave-forms and that their spectra of P wave are expressed approximately by the simple function, $t^p e^{-1.2t}$, where p is of the order of 1 to 4. The larger the magnitude, the greater the value of p. This group includes mostly earthquakes deeper than about 40 km. The P wave-form seems to become sharper with the increase of the focal depth, when earthquakes of a similar magnitude are compared.

Another group includes mostly shallow earthquakes, whose P wave-forms are oscillatory, namely they have a large back swing. The P wave of these earthquakes is considered to consist of two successive events, both assumed to have begun at the origin. Each of these two events seems to be of a somewhat different spectral structure from the former group. These facts may suggest that there is some essential difference in the nature regarding the radiation mechanism of a seismic body wave between the two groups of earthquakes, one occurring in the crust and another in the mantle.

Free Oscillations of the Earth Observed by a Gravimeter at Brussels

By Ichiro NAKAGAWA, Paul MELCHIOR and Hitoshi TAKEUCHI

Communications de l'Observatoire Royal de Belgique N° 236, Série Géophysique
N° 69, September 1964, pp. 108-121.

Abstract

Free oscillations of the earth excited by the great Chilean earthquake on

May 22, 1960, have been observed with various instruments. Among these observations, one with a LaCoste-Romberg tidal gravimeter has been reported by Ness and others. Also, two Askania gravimeters were working at Kyoto at the time of the earthquake. Spectral peaks obtained by these observations were mutually consistent and their peaks agreed with periods theoretically predicted on the basis of the Gutenberg earth model.

At the time of the Chilean earthquake, another Askania gravimeter was working for the purpose of observing the tidal variation of gravity at Brussels. Records were read at 2-minute intervals beginning on May 24, 00 h 00 m, 1960 (UT), the number of readings being 1830. In order to remove the gravity variation due to earth tides and drift of the gravimeter, a high-pass filter was applied twice to all the values read, and the values obtained were analysed by Fourier's method. The analysis was carried out for the 1830 values and for four intervals of 1480 readings taken within this period, because of the preparation for calculating Q value.

Peaks corresponding to fundamental spheroidal modes with periods of 55 minutes to 4 minutes obtained by the analysis agreed with theoretical periods based on the Gutenberg earth model. Some peaks, corresponding to fundamental modes, were missing, whereas the first and second overtones for several modes were observed. Among peaks obtained by this analysis, a peak corresponding to the speroidal mode ${}_0S_2$ was the largest. Moreover, the ${}_0S_2$ peak had maxima at 55.20 and 52.85 minutes for each interval.

A similar separation in spectrum was also recognized around a period corresponding to mode ${}_0S_4$, although it was less clear than that for mode ${}_0S_2$.

For comparison purposes, records obtained simultaneously at Kyoto were analysed by the same methods as was used for records at Brussels. The results obtained from the Brussels records agreed with those from the Kyoto records.

Q, calculated by using the results from the Brussels records, was about 400 for mode ${}_0S_7$ and 200 to 100 for fundamental spheroidal modes with periods shorter than 10 minutes. Similar values for Q were obtained from the Kyoto records.

A Program for Lecolazet's Method in Harmonic Analysis written for IBM 7094

By Ichiro NAKAGAWA

Communications de l'Observatoire Royal de Belgique N° 236, Série Géophysique N° 69, September 1964, pp. 403

Abstract

Since Lord Kelvin introduced the method of harmonic analysis, it has been developed by many people, and there are now various methods available. Among them, Lecolazet's method has been used widely to analyse earth tidal data observed by gravimeters.

With the remarkable progress of the electronic computing machine, several programs for harmonic analysis have been written. A program for Lecolazet's method was first written by P. Melchior and Maria T. Carrozzo for an IBM 650, and by P. Melchior for an IBM 1620. The program written by P. Melchior has been used at the Centre of Earth Tides for analysing data obtained at various stations in the world.

A program for Lecolazet's method has been newly written for an electronic computer, the IBM 7094. The program is based on ' La méthode utilisée à Strasbourg pour l'analyse harmonique de la marée gravimétrique ' reported by R. Lecolazet in "Marées Terrestres, Bulletin d'Informations, N° 10" and it consists of two parts : one is a calculation of observed amplitude and phase, and the other of homologous amplitude and phase. The former includes data correction for jump, data selection, elimination of drift, calculation of amplitude and phase of observed tides, as well as calculation of error. The latter includes calculation of geodetic coefficients, calculation of arguments, and calculation of amplitude and phase of homologous tides.

In order to utilize usefully the memory of the computer, coefficients for calculation are put ahead of data cards in both programs. To use the program for observed tides, the following three conditions must be adopted : (1) interruption of data must be entirely interpolated prior to harmonic analysis ; (2) time interval of selected data should be one hour ; and (3) all data after filtering must be changed into positive numbers by adding a constant. The user can give a FORMAT for reading data or filter function by a card in the program for observed tides. This program is therefore available for data punched in any FORMAT.

Calculation time for four consecutive analyses was 34 seconds for the program of observed tides and 26 seconds for the program of homologous tides.

On the Characteristic Numbers derived from Tidal Observations

By Ichiro NAKAGAWA

Journal of the Geodetic Society of Japan, Vol. 10, No. 2, December 1964, pp. 51–60.

Abstract

Three characteristic numbers h, k and l, related to the elastic behaviour of the earth, have recently been obtained from tidal observations in various regions of the world. The value of the characteristic numbers should, in principle, be equal at any point on the earth's surface. Yet the values, obtained at many stations, are not always identical and a regional difference is clearly recognized in the values of the characteristic numbers.

The most reliable value of diminishing factor $D \equiv 1+k-h$, derived from tidal observations with horizontal pendulums, is 0.68 in Asia and 0.72 in Europe and that of the gravimetric factor $G \equiv 1-3k/2+h$, obtained from tidal observations with gravimeters, is 1.14 in Asia and 1.19 in Europe. Combin-

ing the value of D with that of G, the values of Love's numbers h and k are calculated as follows :

$h=0.68$ and $k=0.36$ in Asia, and
$h=0.46$ and $k=0.18$ in Europe.

Tidal observations with extensometers show that the value of Shica's number l is very close to 0.05 in Japan and 0.07 at Freiburg, West Germany. By using the value of k, thus obtained, and assuming that the value of l, obtained at Freiburg, is applicable to other stations in Europe, the value of $L\equiv 1+k-l$ is calculated to be 1.31 in Asia and 1.11 in Europe.

On the other hand, the most reliable value of L derived from observations of latitude variations is 1.30 in Asia and 1.11 in Europe, which almost exactly agrees with that of L derived above.

In case of a simplified earth (assuming that matter within the earth is absolutely incompressible and that to density and rigidity are uniform) mean rigidity is calculated to be 9.73×10^{11} dyne/cm^2 in Asia and 1.61×10^{2} dyne/cm^2 in Europe, by using the value of h obtained above.

The value of the characteristic numbers is one for M_2-constituent with a speed of 12.421 mean solar hours. The M_2-constituent has the wave length of about 20,000 kilometres. It seems natural, therefore, that a value of the characteristic numbers depends on the elastic behaviour of materials over a fairly wide region, such at Asia or Europe.

On the Natural Periods of Vibration of Structures Measured from Field Survey

By Kiyoshi KANETA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, 1964, pp. 134-140.

Abstract

For the earthquake-resistant design of structures, building code regulations in many countries specify various criteria for finding the value of design lateral forces, based on the dynamic consideration of the response of structures to severe earthquake motions. The Japanese building code provisions specifically applicable to high rise structures of multi-story buildings require a design lateral force in terms of base shear coefficients, determined by a formula which is a function of the natural period of vibration of the structure.

Under these circumstances, an appropriate estimation of the natural period of vibration of structures, if done as reasonably as possible, is a very important step in earthquake-resistant design. However, it is, in general, difficult to obtain a good approximation. Data about the natural period of structures measured for actual building are plentiful, but little has been known about a number of factors, or parameters, affecting the value of the natural periods. Calculations of periods on the basis of the theory of dynamics or vibrations have been attempted for quite a few structures; the

results, however, were that the discrepancy between the values of computed and measured periods was too large to allow the practical application of Rayleigh's or other theoretical procedures to find the fundamental period of vibration. It was not that the theories themselves had an important defect, but that the parameters, or physical quantities, were so involved that one had to assume for unknowns even if they were unreasonable.

Experimental formulae have, on the other hand, proved considerably better and have good approximations for practical purposes. Although some of them were rather intuitive, the remainders have chosen only a small number of important factors. This paper has compared almost all experimental formula and discussed, to some extent, the significance of basic parameters affecting the natural periods. Moreover, a historical summary of previous studies in this field has been given, while some considerations were made to reconcile the formula with the natural periods of vibration of structures measured from field survey.

Report on the Preliminary Survey of Building Damage Due to the 1964 Niigata Earthquake

By Kiyoshi NANETA, Yoshihiro TAKEUCHI and Teizo FUJIWARA

Transactions of the Architectural Institute of Japan, No. 103, October 1964, p. 133.

Abstract

A severe earthquake occurred on June 16, 1964, with the epicenter located near Awashima Island on the Japan Sea. There rerulted remarkable damage to buildings and traffic facilities. It was reported that the magnitude of this earthquake was 7.7, compared to 7.9 of the 1923 Tokyo earthquake and was greater than that of the Fukui earthquake in 1948. The authors were dispatched to the damaged area with some of the staff of the Disaster Prevention Research Institute, Kyoto University, to make a preliminary survey specifically on the damage to building structures in and out of Niigata City, Niigata.

The survey took five days and the data available were assembled and reconciled. At the end of the survey it was found that the major damage to buildings was concentrated in downtown Niigata City, where the bases of damaged buildings were on silty sand. The initial micro-tremor of this earthquake of 3.0 to 4.0 seconds recorded at Shibata City and of 2.5 to 3.0 seconds at Murakami City, both in Niigata Prefecture was followed by ground motion of pretty long periods with large amplitude. A seismometer located at the Niigata City Meteorological Observatory was out of scale, right after it had recorded a ground displacement of about 6 cm. The maximum ground acceleration was estimated at about 150 to 200 gals in downtown Niigata City. Correlation between the number and grade of the damaged buildings and properties of the ground was very evident and the so-called quicksand phenomenon was observed everywhere on sandy ground ; this was one of the features

particularly noted in this earthquake.

Many buildings in downtown Niigata were unduly settled down or tilted, especially reinforced concrete buildings without a basement. However, ferro-concrete multistory buildings with a basement were sound, even in the most affected area. An example of good earthquake resistance was also an electric power station, whose foundation was reasonably designed.

The preliminary report indicated the necessity for fundamental and detailed analyses in the future on the relationship between ground properties and damage to structures.

Experimental Studies on the Buckling Strength of Angles

By Y. Yokoo, M. Wakabayashi and T. Nonaka

Transactions of the Architectural Institute of Japan, Vol. 100, July, 1964, pp. 34–40.

Abstract

In order to observe the fundamental behaviour and strength of mild steel columns of angle section, a series of bucking tests were conducted for various eccentricities and various slenderness ratios, using structural steel with a L-90 mm×90 mm×7 mm profile. A total of fifty-seven specimens were tested. The test results were compared with those derived from buckling theories, and a general consensus was reached between them.

End supports were designed so that the desired boundary conditions could be obtained. Oil pressure was utilized in order to eliminate the resistance against rotation and twisting at the specimen ends. Dial gauges and wire strain gauges were used to observe the behaviour of a specimen or the deformation pattern.

It was observed that various types of buckling caused the failure of angles under longitudinal compression. Flexural bucklng in the direction of the symmetric axis of the cross-section, local bucklng in the legs, and flexural torsional buckling play an important role in the strength of angles.

In case of centrally compressed angles, buckling occurred under elastic bending for long columns, and maximum loads agreed with the critical loads predicted by Euler's theory. For short columns, experimental results showed a good agreement with the flexural torsional buckling theory for thin-walled columns, when elastic moduli were replaced by tangent moduli.

Angles under eccentric thrust in the symmetric plane showed a typical behaviour of columns subjected to bending and compression. Maximum loads were predicted quite well by Ježek's theory which adopted elastic-perfectly plastic stress-strain relationship.

For columns with eccentricity in the direction of the asymmetric axis of the cross-section, the flexural torsional buckling theory had a close agreement with the experiment in the elastic range. In the plastic range, a few modifications were made for the local buckling theory of plate elements, and for the short column theory, in order to gain access to experimental results.

It has been found, both theoretically and experimentally, that the initial twisting of a column does not affect the critical load, provided the angle of twist is distributed linearly along the column axis.

Aseismic Design Method of Elato-Plastic Building Structures

By Takuji KOBORI and Ryoichiro MINAI

Bulletin of Disaster Prevention Research Institute, Kyoto University,
No. 68, March, 1964.

Abstract

A structure composed of ductile materials should be designed according to the ultimate elastoplastic aseismic design method for very intense earthquakes, as well as according to the elastic aseismic design method for moderately intense earthquakes. The procedure of each design method consists of the following two stages: At the first, the aseismic design data for the members and joints of a structure should be obtained by earthquake response analyses; Namely, a group of earthquake excitations, a model of the structural system, and the primarily important measures of aseismic safety should be comprehensively considered. Then the optimum dynamic characteristics which make the responses of the structural system to the prescribed group of earthquake excitations remain uniformly within their allowable values are determined by parametric surveying, of the results of an earthquake response analyses. However, these optimum dynamic characteristics, determined only from the standpoint of earthquake engineering, may be different from the dynamic characteristics of the real structure, designed under actual loading conditions. Moreover, the aseismic safety of a structure may not always be exactly guaranteed by the comprehensive estimation of the aseismic safety at this first stage. At the second stage, therefore, the concrete and exact model of a structural system is chosen, and its aseismic safety reexamined in detail by measures suitable to each structural element.

In this paper, the general procedure of the first stage of the ultimate elastoplastic aseismic design method for a ductile structural frame is discussed in detail. The earthquake response analyses of multi-degrees of freedom system with the bi-linear hysteretic characteristics are carried out by making use of a digital or an analog computer. The effects of both the wave shape function of earthquake excitations and the rigidity ratio of the second bi-linear branch to the first branch on the earthquake responses, are particularly taken into consideration. As a result, the aseismic design data for the initial structural design of an elasto-plastic building structure, which are the shear coefficients, the lateral force coefficients, the elasto-plastic potential energy coefficients and the formula for calculating the fundamental natural period are derived from the optimum dynamic charateristics determined by the above-mentioned earthquake response analyses.

Earthquake Response of Elasto-Plastic Multi-Story Building Structure

By Takuji KOBORI and Ryoichiro MINAI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 141-163.

Abstract

The aseismic design data (adopted for the initial structural design of a multi-story structural frame composed of ductile materials) can be reasonably derived from the elasto-plastic response analyses of structures subjected to strong motion earthquakes. The basic procedure to obtain them consists of the following steps: 1) Supposition of a group of earthquake excitations. 2) Supposition of a model of the structural system. 3) Selection of the measures of aseismic safety. 4) Non-dimensional earthquake response analysis. 5) Determination of the optimum dynamic characteristics. 6) Derivation of the aseismic design data.

In this paper, to obtain the aseismic design data of the tall ductile structures with comparatively long fundamental natural periods, the elasto-plastic responses of a five-degrees of freedom system, due to two typical but different earthquake excitation patterns, are analyzed by making use of an electronic analog computer. And the important earthquake responses, as the measures of aseismic safety, the maximum ductility factor, offset factor and the maximum overturning moment factor, are estimated in the wide ranges of parameters concerning the structural models and the earthquake excitation groups. On the other hand, as a measure of suitability of the distribution of dynamical coefficients, the ratio of the standard deviation (with respect to space variable) of the standardized maximum ductility factor, which is defined by the ratio of the maximum ductility factor to the distribution coefficient of the allowable ductility factor, is calculated in the above-mentioned ranges of parameters.

As the result, it has been found that the wave shape function of earthquake excitations has only little effect on the qualitative characteristics of earthquake responses, but considerable effect on quantitative characteristics. Also, the assignment of slightly positive rigidity ratios of bi-linear hysteretic characteristics remarkably stabilizes the earthquake responses and decreases their variance. From these facts, it is suqgested that the standard values of the optimum dynamic characteristics are largely effected by the wave shape fuaction, and that the distributions of the optimum dynamic characteristics with slightly positive rigidity ratios have a great significance in obtaining a reasonable aseismic design.

Therefore, taking into consideration the effect of the wave shape function and the rigidity ratios, aseismic design data are presented in forms suitable to a practical asismic design.

Ground Compliance of Rectangular Foundation and its Simulation

By Takuji Kobori, Ryoichiro Minai and Yutaka Inoue

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964. pp. 164–178.

Abstract

In considering the earthquake response of building structures, it is very important to estimate reasonably the effect of the dynamic characteristics of the ground on the dynamic behaviour of above-ground structures. Recently, a study on the dynamical compliance of rectangular foundations was presented by Prof. W. T. Thomson and T. Kobori, this has been extended by the authors and Mr. Suzuki.

In this paper, the simulation of the ground compliance of a foundation is presented for the purpose of the non-stationary, non-linear earthquake response analysis of the structural system, consisting of an elasto-plastic above-ground structure, an elasto-plastic adjacent sub-soil and an elastic ground.

Based on conditions both of physical realizability and mathematical stability, the simulation formnla of the complex transfer function of a foundation on the three-dimensional elastic ground into a linear transfer function expressed by the rational function is obtained through the conditional least mean square problem.

Making use of their approximated linear transfer function of the foundation and inserting the non-linear transfer characteristics of the boundary layer (the adjacent sub-soil) between the elasto-plastic structure and the elastic ground, the non-stationary, non-linear responses of the structural system subjected to an arbitrary excitation pattern can be easily calculated by means of a digital or an analog computer.

As an example, the ground compliance of a rectangular foundation on an elastic half-space, which is evaluated by the theoretical solution, is approximated to the linear transfer function expressed by a rational function having the second degree denominator, and simulated to an electronic analog circuit consisting of two summing integrators, two sign changers and four potentiometers. The accuracy of the real and imaginary parts of the approximated transfer function is found to be quite good, by comparing the exact values from the theoretical ground compliance with those of the approximated transfer function. Also, it has been verified that the analog circuit of a dynamic system con-taining the simulated transfer function has shown good results with the computing error remaining in the allowable range from an engineering point of view.

Earthquake Response of the Structure, Considering the Effect of Ground Compliance

By Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964. pp. 179–194.

Abstract

Either in verifying the aseismic safety of a structure, or in deriving the aseismic design data for the initial structural design, it is very important to consider the effect of the dynamic characteristics of the ground on the responses of a structure subjected to earthquakes.

In this paper, the method of the earthquake response analysis of the structural system (consisting of an above-ground structure, boundary layer and the ground) is presented. The dynamic characteristics of the foundation on an elastic ground is approximately expressed by the linear transfer function having the form of a rational function, and this can be easily connected to the transfer characteristics of the boundary layer and the structure.

In general, the earthquake response analyses of the structural system should be performed in the following two ways, depending upon the nature of earthquakes: The elastic response analysis, either statistical or non-statistical, must be applied in the case of moderately intense earthquakes. On the other hand, the elasto-plastic response analysis should be considered in the case of very intense earthquakes. In relation to the first case, the analytical expressions of the statistical responses, (i.e. the co-variance matrix and corresponding spectral density matrix of the output responses of a coupled linear dynamic system due to a non-stationary, Gaussian random input) are obtained. And, particularly in the latter case, the block-diagram of the coupled elasto-plastic dynamic system and its corresponding electronic analog circuit are presented and the basic process obtaining the aseismic design data through the elasto-plastic response analysis is considered. Naturally this analog computer method can be applied to the former linear case.

As the first step, the non-stationary responses of the linear coupled dynamic system (subjected to a band limited white, Gaussian random noise) are analyzed by using an electronic analog computer, the results are then represented in the response diagrams of maximum relative displacement and maximum overturning moment. The behaviour of the analog circuit concerning the approximated transfer function of the foundation on an elastic ground is found to be quite satisfactory.

Dynamical Properties of an Elastic Ground

By Takuji KOBORI, Ryoichiro MINAI and Tamotsu SUZUKI

Reports of the Architectural Institute of Japan (Kinki Subdivision),
February, 1964, pp. 1–7.

Abstract

It has been broadly recognized that the properties of the ground greatly influence the earthquake response of structure. For instance, if the relative stiffness of the structure to that of the ground becomes large, then the dynamical behaviour of the structure is significantly influenced by the ground. In order to find out these relations we must, first of all, examine the dynamical properties of the ground, then investigate the dynamical behaviour of a structure on the ground as a coupled system. As the basic study, one of authors presented the analytical solution representing the dynamical response of the rectangular foundation on an elastic half-space in cases of vertical and horizontal translation and rotation about a horizontal axis. He also made the numerical evaluation in the case of vertical translation.

In this paper, the numerical evaluation for horizontal translation is developed. The solution is represented by the ratio of the displacement to a harmonic disturbing force, which we call the ground compliance of the rectangular foundation. It is an important quantity that represents the dynamical properties of the foundation on an elastic ground. It depends on the elastic constants of the ground (density, shear rigidity and Poisson ratio), the shape and dimension of the foundation area, and the frequency of the disturbing force.

The result is expressed by the complex number involving the residue term at the Rayleigh Pole. Its imaginary part is concerned with energy dispersion to the ground, i.e., waves radiated only from the source at the surface of an elastic half-space, where no reflections exist at the infinite boundaries.

The ground compliance itself varies with the frequency of the disturbing force. However, if it is replaced with the dynamical coefficients of the system consisting of a linear spring and dashpot it is found that the equivalent coefficients are nearly constant with respect to the frequency, at least in the low frequency range. This indicates the possibility that the dynamical property of elastic ground can be replaced with a spring-dashpot system in the case of low frequency excitation. Also the equivalent spring constant and the equivalent viscous damping coefficient can be determined, unrelated to the frequency, by the shape and dimension of the foundation area and the elastic constants of the ground.

Aseismic Design Method for an Elasto-Plastic Tall Building Structure

By Ryo TANABASHI and Takuji KOBORI

Proceedings of the Symposium on High-Rise and Long-Span Structures, Tokyo, September, 1964, pp. 17–27.

Abstract

Aseismic design should offer reasonable dynamic characteristics to a building structure so that earthquake responses to a group of the prescribed earthquake excitations remain uniformly within their allowable values. The principle and method of aseismic design should not to be uniquely determined, since they should be appropriately chosen depending on the structural material, the type of structural system, the function of the building, the intensity of earthquake excitations and so on. A typical structural frame composed of ductile materials should be designed in accordance with the following two methods, depending upon the nature of earthquakes: The ultimate elasto-plastic aseismic design method should be applied in the case of very intense earthquakes with small frequency of occurrence. The elastic or equivalent elastic aseismic design method, on the other hand, should be considered in the case of moderately intense earthquakes with large frequency of occurrence. To establish a design method corresponding to the specific principle of aseismic design, the following two stages should be considered: At the first stage, aseismic design data for the members and joints of the structure must be obtained from the optimum dynamic characteristics determined by earthquake response analyses. The structural system should essentially be designed according to aseismic design data, combined with wind-proof design data and so on. In general, the dynamic characteristics of the real structure may be different from the optimum dynamic characteristics determined only from the standpoint of earthquake engineering. Also, the real aseismic safety of a structure may not always be guaranteed by this comprehensive estimate of aseismic safety at this stage. Therefore, at the second stage, a concrete and accurate model of the structural system should be made and the aseismic safety should be reexamined in detail with respect to each structural element.

In this paper, the first stage of the ultimate elasto-plastic design method for tall, ductile building structures is discussed and a procedure for obtaining aseismic design data for the initial structural design is presented.

On the Simulation of Coupled Ground-Mass System, Based on Dynamical Ground Compliance

By Takuji KOBORI, Ryoichiro MINAI, Yutaka INOUE and Tamotsu SUZUKI

Transactions of the Architectural Institute of Japan, Vol. 103, October, 1964, p. 100.

Abstract

In considering the earthquake response of buildings and other above-ground structures, it is very important to know the dynamical property of the ground. Recently, authors defined it as ground compliance derived from the theoretical solution for the dynamical response of the rectangular foundation on an elastic half-space. They also partly produced, the numerical evaluation of the solution in cases of vertical and horizontal translation. Ground compliance is defined by the ratio of the complex amplitude of the dynamical response of the rectangular foundation to the magnitude of a harmonic disturbing force. That is, the ratio is the linear transfer function of the foundation on an elastic ground.

In this report, the authors intended to offer an approximate expression of the transfer function from the numerical results of the theoretical solution of ground compliance. The aim of this study is as follows: (1) To apply ground compliance to the nonstationary response analysis of the structural system, by connecting the transfer function of the foundation on the ground with the above-ground structure. (2) To investigate the effects of the ground on the earthquake responses of such structural systems, making use of a digital or an analog computer.

The simulation of ground compliance is performed by taking account of conditions, both of physical realizability and mathematical stability, and the transfer function is approximately expressed by the rational function. As an example, this simulation method can be applied in the case of horizontal translation, with the order of the rational function as $N=2$, and the shape coefficient of the rectangular foundation an $c/b=2$. The accuracy of the approximation is quite good even in the case of $N=2$.

This approximate transfer function can be readily simulated by the equivalent circuit of an analog computer, making use of two integrating amplifiers and two summing amplifiers in the case of $N=2$. Moreover, if the circuit representing the elasto-plastic property of the surrounding ground is introduced between the elastic ground and the above-ground structure, the earthquake responses of a structural system involving the surrounding- and elastic-ground can be readily calculated. The methods for such a response analysis and the results derived will be presented in other reports.

Linear Earthquake Response of the Elastic Structural System, Considering the Effect of Dynamical Ground Compliance

By Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE

Transactions of the Architectural Institute of Japan, No. 103, Oct., 1964, p. 101.

Abstract

This paper deals with the method of response analysis a ground-structural system subjected to earthquake motions. The structural system consists of a structure on an elastic ground and a surrounding sub-soil between the structure and the ground. The structure and the sub-soil are idealized to a shear type system of four degrees of freedom. The dynamical characteristics of an elastic ground are represented by a linear transfer function which is obtained, approximately, from the ground compliance of a rectangular foundation on an elastic half-space.

The analytical solution of a linear, transient problem of such a structural system is presented in terms of an impulsive response matrix and a generalized excitation vector. Also, the non-stationary responses are calculated with an electronic analog computer. In this response analysis, the horizontal, linear responses (subjected to a random ground excitation represented by a band limited white noise) are analyzed.

For the purpose of studying the effect of the frequency relation between the system and the excitation on responses, the ratio of the upper frequency limit of the band limited white noise to the fundamental natural frequency of the system is moved over a wide range. The whipping phenomenon is found in cases where natural frequency of the structural system is comparatively large and maximum relative displacement of the top story of the structure is considerable. On the other hand, the maximum relative displacements of each story are uniformly distributed in cases of a small natural frequency of the system. The sum of the maximum relative displacement of the sub-soil and that of the elastic ground is found to be at most a quarter of that of the above-ground structure.

As another variable parameter, the ratio of the mass of the sub-structure to the density of the elastic ground multiplied by the cubic of the dimension of the rectangular foundation is introduced. The variation of this parameter does not noticeably influence the maximum relative displacement of the system.

Non-linear Earthquake Responses of the Elasto-plastic Structural System Considering the Effect of Dynamical Ground Compliance

By Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE

Transactions of the Architectural Institute of Japan, No. 103, Oct., 1964, p. 102.

Abstract

The transient, non-linear responses of a coupled ground-structure system subjected to a random earthquake excitation are analyzed by means of an electronic analog computer.

The coupled dynamic system is considered to consist of three-degrees of freedom, shear type structure with bi-linear hysteretic characteristics, one-degree of freedom adjacent sub-soil with the same characterictics and an elastic ground having the transfer function expressed by a rational function. The wave shape function of the acceleration of earthquake excitation is obtained from the finite time duration of the output of a noise generator, which produces a stationary Gaussian random time function with the band limited white spectrum. As the non-dimensional output responses of the coupled dynamic system, the maximum relative displacement, the maximum ductility factor, the total dissipated hysteretic energy factor, the offset factor and the maximum overturning moment factor are considered.

For the convenience of analysis, it is assumed that the distributions of the dynamic coefficients of the structure are those of the optimum dynamic characteristics with 20% rigidity ratio of bi-linear hysteretic characteristics which are found by the response analysis for the above-ground structure and the El Centro type earthquake excitation. It is also assumed that the boundary layer (adjacent sub-soil) has the bi-linear hysteretic characteristics with 5% rigidity ratio and that the rigidity of the first branch is 40 times more than that of the lowest story of the structure. Moreover, supposing that the structure is a tall ductile building structure with a long fundamental natural period and the ground has considerable rigidity and strength, the elasto-plastic responses of the coupled system are evaluated by the wide ranges of the parameters of structural models and earthquake excitations.

As a result, it is found that the responses of the structure are mainly affected by the strength and frequency parameters of the earthquake excitation, and are little influenced by the parameters of the boundary layer and the ground. From this, it is suggested that, as far as a tall ductile building structure on the comparatively rigid ground-foundation system is concerned, the dynamic characterestics of the ground may have little effect on the earthquake responses of the structure. However, it has also been noticed that the responses of the boundary layer and the elastic ground are largely affected by their relevant parameters.

Complex Eigenvalue Problem in Structural System Having the Approximate Transfer Function of a Foundation on Elastic Ground

By Takuji KOBORI, Ryoichiro MINAI and Tamotsu SUZUKI

Transactions of the Architectural Institute of Japan, No. 103, Oct., 1964, p. 103.

Abstract

In the techniques of earthquake response analysis, it is important to obtain the analytical expressions of the non-linear, transient responses of a structural system subjected to an arbitrarily, deterministic excitation, as well as to find the statistical formulation of the linear non-stationary responses of the structural system due to random excitations. The first problem is particularly concerned with estimation of the accuracy of the responses computed by a digital or an analog computer, making use of the numerical integration method or equivalent analog circuit. As the non-linear characteristics of the structural system are approximated by the poly-linear hysteretic loop, the transient responses of the system can be obtained by successively connecting the solutions in the adjacent linear branches. In the latter problem, the analytical expressions of the covariance matrix, and the corresponding spectral density matrix of the responses of a linear lumped system subjected to non-stationary Gaussian random excitation, were recently investigated by the authors. In both cases, the most important problem was to determine the analytical expression of an impulsive response matrix of the structral system.

In this paper, the structural model is assumed to be a linear, lumped system containing a transfer function expressed by a rational function which is approximately determined from the ground compliance of a foundation on elastic ground. The problem of obtaining the impulsive response matrix of such a coupled dynamic system is essentially reduced to the complex eigenvalue problem, because of the independence of the damping characteristics of the structure and the ground.

Assuming the transfer matrix be asymmetrical, a generalized orthogonal operator is defined, and two sets of normalized orthogonal complex eigenvectors are obtained. The impulsive response matrix of the system is expressed in terms of a set of complex eigenvalues and two sets of complex eigenvectors. It has been noticed that the time factor of the impulsive response matrix contains the sinusoidal functions having phase angles expressed by the function of space variables.

As an example, the complex eigenvalues and the normalized complex eigenvectors were calculated in the case of a coupled structural system consisting of four degrees of freedom, shear type system with linear transfer characteristics and an elastic ground represented by the second order rational transfer function.

Numerical Computation of the Autocorrelation Function and the Spectral Density

By Takuji KOBORI, Ryoichiro MINAI and Yoshihiro TAKEUCHI

Transactions of the Architectural Institute of Japan, No. 103, October, 1964, p. 105.

Abstract

When the finite length of a continuous wave shape, (which can seem part of a stationary time function) is analyzed statistically by a digital computer, it is necessary to express the continuous wave shape as the discrete time series and to compute various statistical quantities, using this approximate wave shape function. Regarding the approximation of the wave shape function, various approximative methods can be considered, making use of a series of delta functions or square wave functions and the piecewise approximation by straight lines or parabolic curves, and so on. In the numerical computation, these approximated wave shape functions are normalized so that the absolute maximum value is unity and the mean value is zero. Using this normalized, approximated wave shape function, the autocorrelation function and the spectral density are calculated.

In this paper the formulas for computing these statistical quantities (using the approximated, normalized wave shape function by the series of square wave functions) are shown. The normalized approximated wave shape function is determined in the following way: The continuous wave shape function is sampled at equally spaced, infinitesimal intervals and the sampled values are normalized so that the absolute maximum value is unity and the mean value is zero. The discrete time series is then replaced by the sequence of the step functions. Making use of this normalized, approximated wave shape function, the autocorrelation function is calculated, and then, using the Fourier transformation, the spectral density is evaluated. In these computational procedures, the above-mentioned approximation of a continuous wave shape can also be adopted to represent the autocorrelation function, and (using this approximated autocorrelation function) the formula for the numerical computation of the approximated spectral density can be obtained.

The approximations reached with the delta function series is probably the simplest case. By using the delta function representation of the autocorrelation function, the formula for the numerical computation of the spectral density becomes the well known formula based on the sampling theorem.

Elasto-plastic Analysis of Framed Structures with Diagonal Bracings (I)

By Koji MIZUHATA

Annuals, Disaster Prevention Institute, Kyoto University, No. 7, 1964. 3 pp. 116-133

Abstract

In the dynamic, earthquake-resistant design of a tall building, the structure has been represented, roughly, by a spring-mass system of many degrees of freedom. However, since bracings and shear walls have been known to be very effective in resisting earthquakes, the dynamic behavior of structures with these earthquake-resistant elements must also be studied.

In this study, the horizontal load-displacement relationships in the elasto-plastic region of some tall buildings with diagonal bracings were investigated, both analytically and experimentally, to give basic data to the dynamic analysis.

The effect of bracings, it is considered, depends on the following : (1) Arrangement of the bracings in the whole building, (2) Arrangement of the bracings in a single storied and single-spanned frame, (3) Ratio of the cross-sections of the bracings to those of the members of the rigid frame, (4) Shape of the cross-section of the bracing, and (5) Vertical load on the structure.

The following three studies were done : (1) A single-storied and single-spanned frame with bracings was taken out of the framed structure of an electric power-plant and its 1/4-scale model was treated, analytically and experimentally, to find the effects of bracings and vertical loads, (2) The second floor (with bracings of comparatively large cross sections) was taken out of the lower part of a 25-storied building and its horizontal load-displacement curve was obtained analytically, and (3) A three-storied, framed structure (with bracings of comparatively large cross sections) was taken out of the lower part of a 25-storied building and its horizontal load-displacement curve of the middle floor was obtained analytically.

These studies were done on the following assumptions : (1) The restoring force characteristics of each member was assumed to be fully plastic, (2) The connections between the rigid frame and the bracings were assumed to be hinges, and (3) The effect of the axial force was only the reduction of the plastic moment.

As a result, the horizontal load-displacement curves were given for each study and the following conclusions were reached : (1) The addition of bracings increases both the initial rigidity and the ultimate load of the structure, (2) The application of vertical loads reduces the ultimate load, and (3) In the experiment, the slip at the joints of the members was fairly large and rigidity was much reduced.

Elasto-plastic Analysis of Framed Structures with Diagonal Bracings (II)

Takuji KOBORI, Koji MIZUHATA and Hideo KUMADA

Transactions of the Architectural Institute of Japan, Vol. 103, 1964. Obtober, p. 86.

Abstract

This paper is the second report of a study on the elasto-plastic analysis of framed structures with diagonal bracings. This study consists of the three kinds of analyses or experiments, two of which were reported in the other abstract by the same authors : (1) A single-storied and single-spanned frame with bracings was taken out of the framed structure in an electric power-plant and its 1/4-scale model was treated both analytically and experimentally, to find the effect of bracings and vertical loads, (2) A three-storied, framed structure with bracings of comparatively large cross-sections was taken out of the lower part of a 25-storied building and the horizontal load-displacement curve of the middle-floor was analysed to find the effect on other floors, and (3) A full-scale model was made from the lower part of a 25-storied structure of the same type as in (1), and bracings of various dimensions were taken and large vertical loads applied. Then, the effect of the dimension of the bracings was investigated analytically. The assumptions force used in this analysis were the same as in the first report : (1) The restoring characteristics of each members were assumed to be fully plastic, (2) The connections between the rigid frame and the bracings were assumed to be hinges, and (3) The effect of the axial force was only the reduction of the plastic moment. As a result, the horizontal load-displacement curves were given for each study and the following conclusions were reached : As the cross-section (both the area and the moment of inertia) of the bracing became large, both the initial rigidity and the ultimate load increased. Also, it was remarkable that the collapse mode (the order of failure of the members) varied as the dimension of the bracing varied, and that the displacement at the beginning of the collapse did not vary noticeably if the bracings had differing dimensions.

Hydraulic Mechanism of Run-Off

By Yasuo ISHIHARA

Hydraulics and Fluid Mechanics, Proceedings of the lst Australasian Conference, 1964, pp. 173–190.

Abstract

Rain, after reaching the ground, flows both over it and in it on its way to stream channels. The hydraulic analysis of this process is important in the

study of runoff. The surface runoff and the subsurface flow are different from the generally accepted groundwater flow which feeds streams over long periods of time. Therefore, the flood runoff can be separated into the direct runoff, which is fed by rainwater flowing on and near the ground surface, and the indirect runoff, which directly corresponds to the groundwater flow. This paper describes the hydraulic mechanism of direct runoff and the analysis of actual flood runoff based upon it.

As the result of several considerations on the rain-water flow on and near the ground surface, it is known that the existence of surface stratum, which is largely porous and is highly permeable, has the most important significance in the occurrence of subsurface flow, and that the travelling velocity of water in a stream channel is considerably faster than that on a mountain slope. Under these conditions a drainage basin can be considered as the equivalent of monoclinal rectangular slope, based upon the equality of the peak discharge from the actual and the replaced basins.

The rain-water flow in such a field of motion can be analyzed as the water flow having distributed inflow. Furthermore, in the field, the resistance law varies from Darcy's to Manning's with the increase of the depth of flowing water. After discussing these characteristics of direct runoff, the methods of replacement of a drainage basin to an equivalent slope and of analysis of the water flow through and on the porous surface stratum were discussed.

Finally, this approach of analysis of flood runoff is applied to that from the Yura River basin, 343km^2 in area. It is shown that this basin has two surface strata with different permeability and thickness. The upper and lower strata are 80 mm and 40 mm in thickness, respectively, and the calculated hydrographs are in good agreement with the observed ones, especially for the period of rain-falling. Then, it is supposed that the model proposed in this paper is available for the further analysis of a hydrograph.

Application of Probability Theory of Two-Dimensions in Determining Design Flood

By Yasuo ISHIHARA and Masashi NAGAO

Bulletin of the Disaster Prevention Research Institute, Kyoto University, Vol. 13, No. 70, 1964.

Abstract

Recently, many reservoirs have been constructed for the purpose of flood control and development of water resources. In establishing the scheme of artificial water control by such reservoirs reasonably the hydrological information available must include the shape of hydrograph during a flood under consideration as well as the peak discharge.

This paper describes the method of evaluation of occurrence probability of the flood hydrograph, and its application to the determination of a design flood.

Firstly, the outline of the available probability theory of two-dimensions is explained, and its marginal distribution function is assumed to be log-normal. Since, usually, there exist only the limited flood hydrographs having a peak discharge over a definite value, the approximate methods of curve-fitting and estimating the correlation coefficient are presented.

Secondly, after discussing the criterion in determining a design flood generally, it is shown that the effect of flood-protection works should be judged by evaluating the occurrence probability of over-flowing of water on embankments or banks. In order to estimate those probability by applying the two-dimensional probability theory, the quantitative representation of characteristics of a flood hydrograph is needed. Such representative factors must be the original or natural ones. It is found that the peak discharge and the duration time, while the flood runoff is showing the half or more value of peak in discharge, of flood hydrograph can be adopted as such two representative quantities in many cases.

Finally, several computative examples of application of this approach are shown for the Yodo River. The following conclusions are obtained:

(1) The design flood should be defined as the flood which has the defined density of occurrence probability and the maximum peak discharge.

(2) The design peak discharge in the net of river channels or a river should be determined so as to co-ordinate the expected flood losses are larger than the others, a reservoir for flood control should be planned.

(3) The ratio between inflow and outflow in operation of the flood control by a reservoir should be determined so as to minimize the occurrence probability of flood losses in the downstream area.

A Study on the Transformation System During Flood Runoff

By Tojiro ISHIHARA and Takuma TAKASAO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, May, 1964, pp. 265–279.

Abstract

The runoff phenomena are essentially the stochastic processes. In order to understand them, it is necessary to find out a macroscopic law on hydrologic transformation from rainfall to discharge and to study the statistical characteristics contained in the law.

The purpose of this paper is to unify the runoff process in a small basin as a dynamical transformation system. On the basis of hydraulic study on the mechanisms of rain-water such as sub-surface flow and its role in runoff process and overland flow with or without rainfall, the runoff processes of flood in a small basin were classified and analyzed in a quasi-deterministic way.

As a result, it was pointed out that there exist three equivalent transformation systems in the runoff processes in a river basin by the condition of rainfall and basin surface. Those systems are non-linar time invariant, NTI,

in which the effective rainfall is equal to the excess one, non-linear time invariant, NTI_e, in which the effective rainfall changes in space as well as in time and non-linear time variant, NTV, in which the occurrence of runoff varies with time and the effective rainfall is the excess rainfall plus the maximum intensity of subsurface runoff over area. By the resson of the existence of three transformation systems and three fundamental patterns in actual runoff process result, they are NTI, NTI_e, and NTI_e-NTV ($NTI_e \rightarrow NTV \rightarrow NTI_e \rightarrow \cdots \rightarrow NTI_e$), where the arrows represent the system transitions.

Nextly, the characteristics of each runoff pattern was analyzed, and the transformation operator from rainfall to discharge was presented, and the significance of the nonlinearity of runoff was cleared in the light of dynamics.

The results obtained in this research play an important role in the analysis and forecasting of runoff in a river basin as small as several hundred square kilometers in area and may be a basis of generalyzed runoff theory.

Studies on Flood Caused by Snow-Melt

By Katsumasa YANO and others

Technical Report of Heavy Snow-Fall in January, 1963, The Special Committee Sponsored by the Ministry of Education, March, 1964, pp. 62-75.

Abstract

This paper described the possibility of flood damage caused by snow-melt, resulting from "the heavy snow-fall in January, 1963," over the district facing the Japan Sea. Since the flood hydrograph is characterized by a lower peak flow and a longer duration time than that from a storm rainfall in Japan, it was supposed that the flood damages would occur in considerably different figure from the ones caused by rainfall. Then, the field observations of variation of a river bed, water seepage through embankments, discharge rate of water from a drainage area covered by snow, and so on were carried out in the Kuzuryu River.

The results obtained by the field observations and the theoretical considerations are as follows:

(1) The availability of so-called degree-day factor in estimating the water quantity by snow-melt was ascertained, based upon the fact that there was the good correlation between the water quantity and the mean air temperature. Furthermore, such a correlation becomes better when several days were taken as the time of averaging the air temperature than one day was. The linearity of the mechanism of runoff by snow-melt was made clear, based upon the constant lag time of a peak flow, and it was found in this case that the method of unit hydrograph was available to estimate a flood hydrograph by snow-melt.

(2) The variation of average river bed in cross-section was not so remarkable during the flood. It was observed, however, that locally, the sand dunes yielded and moved downstream and, thereby, the foundation of embank-

ment was scoured a little.

(3) It was found from theoretical consideration that the larger width of embankment is desired for the river with a flood caused by snow-melt than that for the river without such a flood, because the seepage phenomenon of water through embankment becomes nearly steady in the case of the flood.

(4) Although the disastrous flood did not occur in this season, many informations of the characters of flood runoff by snow-melt and the matters that demand special attention on construction of various hydraulic structures are very usefull in establishing the scheme of flood-protection.

Studies on Hydraulic Jump and Its Effect on Energy Dissipation

By Hiroji NAKAGAWA

Proceedings of the First Conference of Science on Disasterous Phenomena, September 1964, pp. 160-163.

Abstract

When the tailwater depth is always less than that necessary to form a hydraulic jump, one solution, to maintain the sufficient depth is to obtain a a provision of a pool by a secondary dam. If the discharging capacity of the outlets is much less than that of the spillways, and only one stilling basin is used to dissipate the excess energy in both operations, it becomes, an important problem to develop the economical and safe design of the stilling device. To satisfy the requirement, the stilling basin with a trapezoidal weir functioned by a performance of a secondary dam in service operation and of a deflector in emergency have been developed in Japan.

Several features of hydraulic jamp formed by the weir under a forced jump state are described herein, based on the experimental data. The pressure measurement has shown that the relative force exerted on the downstream face of the weir increases linearly with increase of the relative position of the jamp X/L_j (X: distance between the toe of jamp and upstream end of the weir; L_j: the length of the nomal jump), and that the dynamic pressure coefficient exerted on the upstream face of the weir has some relationship with X/L_j and relative height of the weir. It has been found ay analysis of the exerting force that ratio of the dynamic force to hydrostatic one exerted on the upstream face is nearly constant for the case of the Froude number F_1 of initial flow less than 4, and abruptly increases for $F_1>4$ with decrease in X/L_j.

The investigation is to make a research of the hydraulic performance of the weir with relatively large height, so that the features of the jump will be distinguished from those of the small scale appurtenances. It is found through the depth measurement that the maximum depth alway occurs behind the weir for $X/L_j<0.8$, which indicates that the undercurrent inside the jump is deflected upward along the sloping face and falls into the tailwater with a standing wave. It is shown by computation of energy of the flow that the

efficiency of dissipation under the forced jump condition increases five to ten percent., compared with that of a normal jump.

On Secular Change of Inflow in Lake Biwa

By Masashi NAGAO

Annuals, the Disaster Prevention Research Institute, Kyoto University,
No. 7, 1964, pp. 254–264.

Abstract

Recently, the development of water resources is desired with the progress of industry in Kinki district. For this demand, more effective use of Lake Biwa is under consideration. In this sense, it is very important to know the trend of the inflow over a long time as the source of water supply. This paper describes the characters of the secular change of the inflow into Lake Biwa by use of the theory of time-series, especially its periodicity and randomness, the possibility of prediction of the inflow and the climatic factors affecting on the annual loss of water, which means the difference between the annual inflow into the lake and the annual precipitation over the whole area.

The results obtained are the followings:

(1) Since the secular change of winter inflow from November to May into Lake Biwa is nearly stationary, that of annual inflow results from the summer inflow from June to October.

(2) The periodicity of about 57 years in the secular trend of annual inflow is discerned by the correlogram analysis of the data from 1875 to 1961. Fitting a sine curve to this periodic change, the peak of sine curve appears in 1903 and 1960, its trough in 1931, and its amplitude becomes 94 cm in water depth of the lake. No special trend can be found out about the residual inflow which is removed from such a periodicity from the annual fnflow.

(3) The prediction by use of the Wiener's theory, basing upon the linear combination of the residual inflows, is little significant in practical meaning from the view-point of preditional error.

(4) Since, owing to the field observation, the secular change of annual amount of evaporation from the water surface of the lake is not so large, the secular change of the annual loss of water seems to be mainly caused by evaporation and transpiration from the ground and the vegitation in the drainage area surrounding the lake.

(5) One of the dominant factors affecting on the annual loss of water is the sun-shine, especially the horizontal isolation, because the secular changes are similar each other.

Study on Automatic Operation of Gate for Flood Control

—Hydraulic Behavior of Water Flow Controlled by Gate—

By Yasuo ISHIHARA and Hiroshi SATO

Annuals, the Disaster Prevention Research Institute, Kyoto University,
No. 7, 1964, pp. 299-310.

Abstract

A number of reservoirs and retention pools for flood control have been constructed and are under planning in Japan. In order to obtain the expected effect of flood control, it is necessary to operate many gates of these hydraulic structures reasonably and organically. However, various problems remain unsolved in performing such a whole system of flood control in a river. This paper describes, as the first step of studies on these problems, the hydraulic behavior of water flow controlled by a gate.

Several experiments are carried out hydraulically by the reservoir model in the concrete channel, being 0.5 m in width and 85 m in length. It is found as their results that the controlled flow behaves as the uniformly progressive flow in the case where there is no secondary weir in the downstream channel from the dam. On the other hand, in the case where there is a secondary weir and the controlled water pours into the stored water, the flow behaves as the hydraulic bore or the so-called initial wave. The uniformly progressive flow is classified, after theoretical consideration, into eight types of flow profile by the scale of change between initial and final flow conditions, and by the ratio of actual slope to critical slope of the channel. And the fow of which the water surface changes continuously is only two cases. In the case where the controlled water pours into the stored water, many initial waves and bores appear and the flow behavior becomes very complicated. The average figure of change of the water surface, however, can be analyzed as the reflecting motion of bore between the dam and the secondary weir.

From these theoretical and experimental results, it is found that this control process may be treated approximately as that having the simple lag and the transport lag in the sense of control enginnering, and that the digital and computer control system are desirable for automatic flood control in a river.

Study on the Sedimentation of Suspended Sediment in Reservoirs

By Katsumasa YANO, Kazuo ASHIDA, Atsuyuki DAIDO and Takeshi MAEDA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 348-364.

Abstract

For the sake of flood control and water resources development, many dams are constructed now in our country. But rivers in our country generally have steep slopes and carry a lot of sediment into the reservoirs. Because

of this many reservoirs constructed years ago have become almost filled with sediment deposits.

Therefore the sedimentation in reservoirs is one of the most important problems in river engineering at present. This paper deals with experiments on the sedimentation of the total load including the suspended load and the bed load into reservoirs.

Experiments were done in a flume of 20 cm in width, 15 m in length, at the downstream end of which a weir of 36.8 cm in height was provided.

Diameter of used sand was from 0.01 mm to 0.3 mm and the mean value 0.052 mm.

The experiment was continued for 4 hrs, and at every hour the profile of the deposited sediment, the vertical concentration of suspended sediment, the grain-size distribution of suspended and deposited sediment for various sections in the reservoir were measured. From the consideration of these data the following conclusion was obtained.

In the bed profile of deposited sediment there occurs a point of abrupt change in bed slope which may be called a front of the delta. This point divides two regions upstream and downstream which correspond to the sedimentation due to the bed load and the suspended load respectively. These regions have very different characteristics from each other with respect to the vertical distribution of sediment concentration and grain-size distribution. In the upstream region the distribution of concentration follows the equation of the equilibrium condition. On the other hand in the downstream region, there is a layer having constant concentration near the bed, in which the turbulent effect may be negligibly small, and the pattern of distribution of the concentration differs very much from the one for the equilibrium condition.

The front of the delta moves downstream with a constant velocity and the depth on the delta has constant value under constant condition. With the use of the experimental results, the authors established an analytical equation to estimate the bed profile of the deposited sediment.

The experiment shows fairly good agreements with the results by the above equation but the estimation of the constant involved should be further discussed.

Study On Reservoir Sedimentation (3)

—On the Back-Sand Phenomena—

By Katsumasa YANO, Kazuo ASHIDA and Yuichiro TANAKA.

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 365–372.

Abstract

For the sake of the flood control and water resouces development, many dams are constructed now in our country. Dams which are constructed in

rivers carrying a lot of sediment produce many difficult problems due to deposited sediments. For example, the rise of the river bed upstreams of the dam and the decrease in effective storage capacity etc. These problems have a large influence on the programs of the construction of dams, namely the plans of the flood control and water utilization in future. Therefore, the sedimentation in reservoirs is one of the most important problems in river engineering at present.

From such points, the authors have done a series of studies on the sedimentation in reservoirs during the past few years. There are two types based on the bed load and suspended load in these phenomena and these occur by quite different mechanisms. The authors have considered only the sedimentation due to bed load in these studies.

It is well known that the bed profile of the sediment into reservoirs generally takes the form of a delta. In the first report, the authors considered theoretically and experimentally the hydraulic behaviors of the delta and made clear their properties such as the depth at the front and the locus of the front. Using these rsults, the authors proposed a method of calculating the bed profile formed by the deposited sediments and verified it by the experiment.

The second report dealt with the river bed variation upstream of the dam filled with sediments, in particular some problems in the calculation by digital computer such as how the boundary condition should be given.

This paper deals with the back-sand phenomena of dams. Back-sand which means the phenomenon of the rise of the river bed due to a structure extends to progressively the upstreams of the structure. From the data obtained in an experimental flume of 150m in length, 60cm in width, the bed profile is assumed to be nearly parabolic. Using this assumption and the continuous equation of sediments, the authors propose a practical method to calculate the progressive velocity of the upstream end of the back-sand and the bed form. The result of the calculation shows fairly good agreement with the experiment.

Study on the Sedimentation in an Abrupt Expansion

By Kazuo Ashida and Hiroshi Miyai

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 329-339.

Abstract

This paper deals with the stream bed variation in an abrupt expansion such as occurs at a river-mouth or around a structure.

At an abrupt expansion there may take place separation of the passing flow from the walls and the formation of eddy zones. In addition to this fact a delta is formed by deposited sediment in the case of movable bed. Due to the interaction between the eddy zones and the delta, the hydraulic behaviors at the abrupt expansion with movable bed differ considerobly from these with fixed bed. Therfore, it is very important to make clear the relation

between the eddy zones and channel forms under various flow conditions in order to discuss the mechanics of the delta.

For these durposes experiments were conducted in a flume of 14m in length, 1m in width, the upstream part of which was narrowed by two kinds of width to make expansions.

The sand having a uniform grain-size of 0.88mm was fed at the upstream end of the channel. The change of the elevation of the sediment bed and water level was measured continuously. It is well known that the eddy zone in an abrupt expansion with fixed bed has a asymmetric character and flow is concentrated to one side which results in the length of the eddy zone on one side becoming generally much longer than that on the other side.

Moreover, the eddy zone is unstable and the concentration of flow easily moves to the other side under the influence of external forces.

From this study it was made clear that the eddy zone formed on a movable bed has a more stable character than the one formed on a fixed bed, and the length of eddy zone was almost the same for both sides.

This fact may be attributed to the automatic control effect of the delta, which should be analytically explained in future.

The other notable fact which was obtained by the experiment is that the length of the eddy zone becomes much shorter than the one on a fixed bed.

In order to explain this fact the authors reduced theoretically a non-dimensional parameter involving the effect of adversed pressure gradient which may control the length of the eddy zone and verified it by the experiment.

As for the energy loss at the abrupt expansion before the equilibrium state, the authors tried some investigations but this problem requires further examination.

On River Bed Variations and Stable Channels in Alluvial Streams

By Kazuo Ashida

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 14, Part 1, August, 1964, pp. 23–45.

Abstract

This paper deals with a theoretical consideration on the river-bed variation and on the hydraulic characteristics in a stable channel with uniform grain-size under constant discharge. In addition to the theoretical consideration, experiments for stable channels through constrictions were carried out. This paper consisists of four chapters. In the introduction to this paper, some problems in the river bed variations and stable channels in an alluvial stream were briefly discussed, based on the classification of these problems. In the second chapter, one-dimentional analysis of river-bed variation was discussed. In the third chapter, the characteristics of stable channels for uniform flow were discussed. In the fourth chapter, two aspects of stable channel for varied flow which are a longitudinal profile and a cross-sectional form were

discussed. From these studies the following summary and conclusion were obtained.

(1) It was made clear that the small variations which would be given in the stable state may be stable in general and the solution representing the process to the stable state was obtained.

(2) The sole value of equilibrium uniform depth, slope and specific energy are determined by the values of Q (discharge), Q_B (rate of sediment transportation), B (width) and d (diameter of bed material).

(3) Equilibrium uniform slope and Froude number remain almost constant even though width B varies while Q, Q_B and d are constant.

(4) The depth and the energy gradient in the equilibrium state in a gradually varied channel will be equal to the equilibrium uniform depth and slope in the uniform channel having the same width as that of the gradually varied channel at each section respectively.

(5) Energy gradient in a channel with movable bed is almost constant in the equilibrium state even though the width varies while the values of Q and Q_B are constant.

(6) Therefore, the energy equation may be conveniently applied to estimate the stable profile in a gradully varied channel and therefore the energy head H_{e0} at the boundary may be a very important factor in obtaining a stable profile.

(7) Stable cross-sections in a non-uniform channel with movable bed take very complicated forms due to the secondary flow depending on the variation in the channel width. Some aspects of these problems were discussed, but further investigations are necessary.

Fundamental Study on Mud-Flow (IV)

By Katsumasa YANO and Atsuyuki DAIDO

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, 1964, pp. 340-347.

Abstract

As a first step in investigating mud-flow, the present paper deals with the deformation and flow of muddy clay. Mud-flow means the flow of terrestrial deposit layer saturated with rain in a mountain stream. In Japan, many human lives and possessions are lost by mud-flow every year. In addition, because of the occurrence of mud-flow, the river bed rises and the mud-flow breaks structures in a river. In order to prevent these disasters, the character of mud-flow should be made clear. Although there are many ways of approach in investigating mud-flow, the problem is discussed here especially from the point of view of establishing the mechanics of the flow. The paper deals with the rheological law of muddy clay. Generally material such as muddy clay deforms according to the Bingham law. It is observed, however, that the slow flow appears even when such clay was loaded by the stress τ smaller then the Bingham's yield stress τ_y in the coaxial cylinder viscometer.

The deformation of materials at a given moment of time t, is the sum of the recoverable and unrecoverable parts of deformations. The former is proportional to the stress; that is an elastic part. The latter is related to the rate of strain; that is a part.

The behavior of the materials may be described by the integral equation of Boltzmann. The deformation ϵ at a certain time t, caused by a stress varying with time is expressed as follows:

$$\epsilon(t)=\frac{\tau}{\gamma}+\tau^{\varphi}\int_0^{t_u}\kappa(t)dt,\quad \kappa(t)=\frac{\epsilon_u}{\tau^{\varphi}}b\left(\frac{t}{t_u}\right)^{b}\frac{1}{t} \tag{1}$$

where γ is a modulus of elasticity, t_u a duration time until the deformation reaches the upper limit of the yield point and b or φ a constant.

Therefore, the deformation at time $t(>t_u)$ is written as

$$\epsilon(t)=\frac{\tau}{\gamma}+\tau^{\varphi}\int_0^{t_u}\kappa(t)+\frac{1}{\mu_B}(\tau-\tau_y)(t-t_u) \tag{2}$$

in which μ_B is plastic viscosity and τ_y the Bingham's yield stress. These equations are applicable when muddy clay is load by a stress τ which approximates τ_y.

On the Artificial Strip Roughness

By Shohei Adachi

Bulletin of the Disaster Prevention Research Institute, Kyoto University, No. 69, March, 1964.

Abstract

The tests were conducted in the 20 cm wide, 30 cm deep, and 14.4 m long steel flume with 1/500 slope. The strip roughness elements, having a rectangular cross-section of 5 mm in height and 6.4 mm in width, were placed on the bottom of the flume with constant longitudinal spacing.

From the results of the measurements of the friction factor, the velocity profiles, and the drag coefficient of the roughness elements, it was concluded that the transitional flow pattern between isolated-roughness flow and wake-interference flow, i.e. incomplete wake-interference flow, should be introduced in addition to the classification of the flow patterns on a rough surface by H. M. Morris.

In this test, these flow patterns were observed when the relative roughness spacing (the ratio of the spacing (s) to the height (k) of the roughness element) was larger than 2.5 and less than 160. The ridge and groove are distinguished from the position of the datum plane although both belong in the same category from the geometric view. The datum plane of the roughness element may be set on a certain middle height of the element when the incomplete wake-interference flow occurs. For convenience, however, the ridge roughness may be defined as more emphatic in nature than the nature of the groove. Similarly concerning the groove roughness, the nature of the groove

is more emphatic than the nature of the ridge. By this convenient definition, the practical criterion between the ridge and the groove roughness is given as $s/k=8$ for the strip roughness used in this test. This criterion corresponds to the condition which produces the maximum resistance. Based on the above criterion, the empirical logarithmic roughness formula for the ridge roughness and the groove was developed in terms of the relative roughness height and the relative roughness spacing.

Flooding Trouble at Iriye-Reclaimed-District

--Studies on Interior Flooding Troubles Derived from Other Workes (1)—

By Mutsumi KADOYA, Eiji TOYOKUNI and Gyozo OHASHI

Annuals, Disaster Prevention Research Institute, Kyoto University
No. 7, March, 1964, pp. 280-289.

Abstract

Iriye-reclaimed-district facing Lake Biwa is circumstantially dangerous from floods, because it is sandwiched between the river Amano and the river Yagura which are both liable to flood. The area behind this district seems to be just divided into two sub-area by a narrow part between the embankments behind this district and the old railways. Regardless of the fact that the existence of such a contracted part has often caused flood damage for this district, recently this part has been more contracted in width by the construction of the new railway.

In this paper, in order to find the extent of the dangerousness of this district from floods caused by this new contraction, the following approach of analysis has been adopted.

(1) The flood hydrographs in the river Amano and the river Yagura caused by heavy rainfalls are estimated by help of the method of characteristics in runoff analysis.

(2) The hydrographs of inflows from the rivers to the area behind this district are estimated under the assumption that, if the water flows over the embankments of the rivers, they will be destroyed.

(3) The draining capacitoies of the contracted part and the drainage channel by which innundated water is directly drained from the hinterland to Lake Biwa, are examined by using the method of reservoir routing, considering the variation of the coefficient of roughness with water depth.

(4) The hydrographs of innundated water in the two sub-areas estimated by considering the runoff in each sub-area itself, the inflow from the rivers to this areas and the draining capacities of the contracted part and the drainage channel.

The influence of the new contraction is evaluated from the point of the increment in the valume of water, which would be introduced into the district, under the conditions as follow, if water in the flooded area is so vast that it overflows and destroys the embankment, a portion of such water is introduced into this district through a gate before overflowing, and the highest water

level in the flooded area is unchanged before and after the construction of the new railway.

Application of Extreme Value Distribution in Hydrologic Frequency Analysis

By Mutsumi KADOYA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 13, No. 66, March, 1964, pp. 1-44.

Abstract

It is well known that there are three types of asymptotes for the distribution of the extremes or largest values, which are expressed as follows:

$F(y)=\exp(-e^{-y})$;

$y=a(x-u)$, for the first asymtote or the Gumbel's distribution,

$y=a\log(x+b)/(u+b)$, for the second asymptote or type A of log-extreme value distribution,

$y=a\log(g-u)/(g-x)$ for the third asymptote or type B of log-extreme value distribution,

in which a, u, b and g are population parameters.

Several problems have remained unsolved in the practical analysis of hydrologic frequency by the use of these asymptotes.

(I) In Part I, first of all, the statistical characters of the three asymptotic distributions are discussed theoretically and it is shown that they should be applicable in limited range of the value of coefficient of skew, C_s, that is

$$C_s \begin{cases} > \\ = \\ < \end{cases} 1.1395\cdots; \quad \text{for} \begin{cases} \text{the second asymptote,} \\ \text{the first asymptote,} \\ \text{the third asymptote.} \end{cases}$$

Next, although methods of estimation of the parameters included in the asymptotic equations have been proposed by Gumbel and others by the help of method of moment, the results obtained by such methods seem to be not so applicable to hydrologic data. Then, a method of estimation based on the concept of plotting value instead of plotting position, proposed by the author is succesfully developed for the first and the second asymptotes from the view point of practical application.

(II) Generally, very large or small data are to be contained in a sample, which is called the singular value. In estimating the population parameters of asymptotes, the rajection test of such data is essential in the sense of stochastics. Moreover, evaluation of the singular value is important from the point of view of engineering.

In Part II, first, applying the concept of two-sample theory on normals the method of evaluation of a sigular value is proposed. Next, on the basis of the binomial distribution, the criterion for rejection of singular data is defined.

Studies on Cnoidal Waves (First Report)
—On the Waves Steepness and Profile—

By Yuichi IWAGAKI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 373-386.

Abstract

The cnoial waves, which were discovered by Kortweg and de Vries in 1895, are not familiar to engineers in spite a long history because of mathematical treatments including the Jacobian elliptic function and the complete elliptic integrals of the first and second kinds. Since, however, it is noticed that the theory of Stokes waves is not appropriate to periodic waves progressing in shallow water whose depth is less than about one-tenth the wave length, but the theory of cnoidal waves should be applied to those waves, it is necessary to modify the theoretical results of cnoidal waves and provide the graphs to find easily the wave characteristics.

The graphs presented are of the first and second approximations of δ/H and H/L against K with a parameter of h/H (δ: the vertical distance from the wave trough to the still water level, K: the complete elliptic integral of the first kind, h: the still water depth, H: the wave height and L: the wave length). Furthermore, to obtain the cnoidal wave profile of the second approximation easily from the solitary wave profile of the first approximation, the graphs are provided of $(\eta_s-\eta_1)/H$ against K with a parameter of x/L and $(\eta_1-\eta_2)/H$ against h_t/H with a parameter of η_1/H (η_1, η_2 and η_s: the vertical distances from the wave trough to the water surface for the first and second approxiamtions of cnoidal waves and for the first approximation of a solitary wave respectively, x: the horizontal distance from the wave crest and h_t: the vertical distance from the sea bottom to the wave trough).

In addition, a comparison of the wave profiles between the first and second approximations of Laitone's solution, Stokes waves of the third approximation and the solitary wave shows that the difference between the solitary and cnoidal waves of the first approximation is 1.5% of the wave height at most when $K\geq 3$ and Wilson-Webb- Hendrickson's criterion for application of Stokes waves is too strict as long as the wave profile is concerned.

The Effects of Wave Height and Sea Water Level on Wave Overtopping and Wave Run-up

By Yuichi IWAGAKI, Akira SHIMA and MASAO INOUE

Proc. 11th Conf. on Coastal Eng. in Japan, Nov., 1964, pp. 253-259.

Abstract

It is very important but difficult to establish general method for determining the crest elevation of a sea wall. This paper includes the consideration

of the effects of wave height and sea water level on wave overtopping and wave run-up, based on the experimental results by Ishihara-Iwagaki-Mitsui and Saville for wave overtopping and by Saville for wave run-up.

First, the replots of Saville's data of run-up are made in the forms of R/L_0 against H_0/L_0 with a parameter of h/L_0, R/H_0 against h/H_0 with a paramter of H_0/L_0, and $(R+h)/H_0$ against h/L_0 with a parameter of H_0/L_0 to find the effects of wave height water depth and sea water level, respectively, in which R is the height of run-up from still water level, H_0 and L_0 the wave height and wave length of deep-water waves, respectively, and h the water depth of of the toe of a seawall.

The results of the replots produce the following conclusions:

1) As to the effect of wave height, the height of wave run-up increases with increase in the wave height when $\tan\alpha \leq 1/4$, in which α is the angle of inclination of a seawall, however, it does not always increase when $\tan\alpha \geq 1/3$.

2) When the wave steepness in the small and α is large, the effect of water depth is remarkable.

3) There exists the maximum value of the height of wave run-up, and it appears when h/H_0 is about 1 to 2 and the wave steepness is smaller than a certain value which is related to the value of α.

4) As for the effect of sea water level, the height of wave run-up from the sea bottom increases with rise of the water level when the wave steepness is large and α is small. However, the maximum height of wave run-up appears especially in some definite cases when the wave steepness is small and α is large.

Second, the replots of the data of wave overtopping on a vertical seawall are made. The conclusions obtained from the replots are described in the abstract of "Some Problems on Prevention of Wave Overtopping on Seawalls and Seadikes".

Some Examples of the Transformation of Ocean Wave Spectra in Shallow Water

By Yuichi IWAGAKI and Tadao KAKINUMA

Proc. 11th Conf. on Coastal Eng. In Japan, Nov., 1964, pp. 49-55.

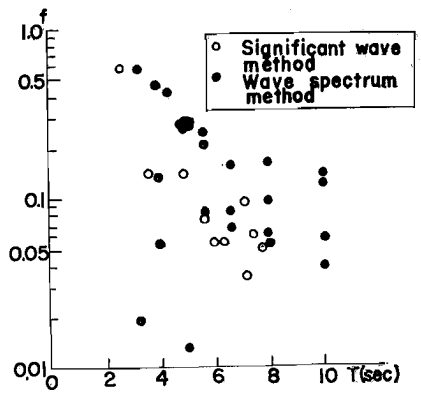
Abstract

One of the most important problems in coastal engineering is the transformation of waves as they approach the shore through shallow water.

This paper, estimates from the damping of the significant wave height and the transformation of the wave spectra observed at the Izumisano Coast and Hiezu Coasts, the lost of wave energy due to bottom friction is investigated quantitatively and the bottom friction factors. In sstimating the bottom friction factor by the wave spectrum method, it is conveniently assumed that each component wave propagates independently.

The values of the bottom friction factors at the Izumisano Coast are estimat-

ed at 0.14 and 0.55 by the significant wave method, and 0.013～0.054 and 0.25～0.55 by the wave spectrum method. At Hiezu Coast, the estimated values are 0.054～0.13 and 0.043～0.44 respectively. It should be noted that these values are much grater than the 0.01 which was given by Bretschneider to be generally used when forecasting ocean waves in shalow water.



It seems that the longer the significant wave period the smaller is the value of the bottom friction factor estimated by the wave significant wave method. In addition, the values estimated by the wave spectrum method seem to have the same tendancy as those estimated by the significant wave method except at three points (Data No. I-1). The figure shows the relationship of the bottom friction factors at the Izumisano, Hiezu and Akita Coasts estimated against wave periods.

Some Problems on Prevention of Wave Overtopping on Seawalls and Seadikes

By Yuichi Iwagaki, Yoshito Tsuchiya and Masao Inoue

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 378-399.

Abstract

In designing seawalls and seadikes, it is very important to estimate the quantity of water overtopping on them as exactly as possible. In this paper, the effects of incident wave characteristics, water depth at the toe of a seawall, the wall height from still water level and wind on the quantity of overtopping water are discussed, based on the results of experiments for vartical seawalls made by the authors and others.

Five figures are presented in order to consider the effects of wave height, wave length, water depth at the toe of a seawall and heights of a seawall from still water level and from sea-bottom on the rate of wave overtopping. The following results are concluded.

The rate of wave overtopping does not always increase with increases in the deep-water wave height and water depth at the toe of a seawall. Therefore, the design wave and the location of a seawall should be decided carefully from view point of disaster prevention. Moreover, increasing the wall height from still water level to decrease the quantity of overtopping water is not so effective when incident waves break just in front of the seawall as for the case of no breaking or after breaking of waves.

The experimental results on the effects of wind on the quantity of overtopping water are represented in dimensionless forms. The effects are concerned

with a Froude number expressed by wind velocity and wave height. There is a definite difference between the cases when incident waves break before they reach the seawall and they do not break. In the former case, there exists the maximum quantity of overtopping water at a certain wind velocity. On the other hand, in the latter case, the quantity of overtopping water becomes large with increase in the wind velocity.

In addition, the model experiments with the scales of 1/15 for the Sakai Habor seawall in Osaka Prefecture and 1/25 for the Yui seawall in Shizuoka Prefecture were performed, based on the Froude similitude. The results of the experiments are compared with those of the experiment for vertical seawalls.

Basic Studies on the Wave Damping Due to Bottom Friction (2)

--On the Measurement of Bottom Shearing Stress—

By Yuichi IWAGAKI, Yoshito TSUCHIYA and Masayuki SAKAI

Proc. 11th Conf. on Coastal Eng. in Japan, Nov., 1964, pp. 62-68.

Abstract

Direct measurements of the shearing stress exerted on a smooth horizontal bottom by progressive, shallow-water waves were made by an instrument similar to that used by Eagleson. It is found from Figs. 1 and 2 that experimental results of friction coefficient agree well with the theoretical relation-

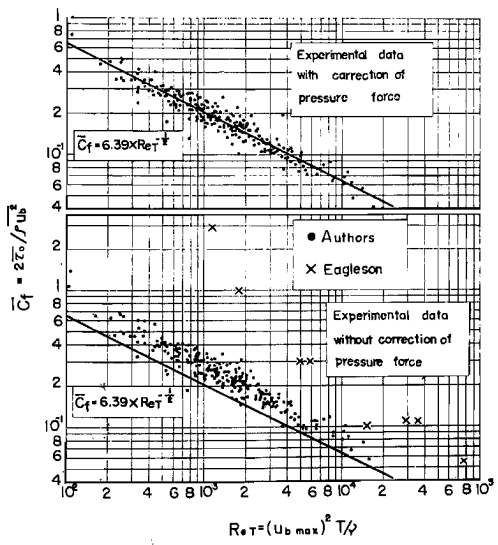


Fig. 1. Relation between friction coefficient $\bar{C}_f$ and Reynolds number R_{eT}.

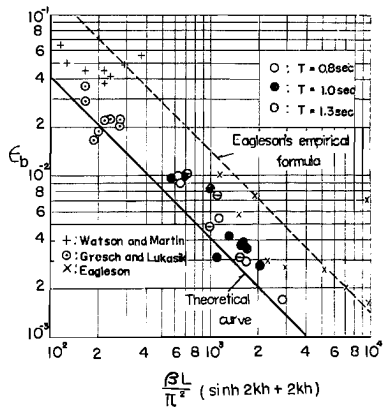


Fig. 2. Comparison between theoretical relationship and experimental results of wave attenuation coefficient ($\beta^2 = \pi/\nu T$, $k = 2\pi/L$).

ship derived from the linearized viscous equations of motion with the correction of the pressure force acting on the shear plate edges due to pressure gradient, and wave attenuation coefficients computed from the data of wave height attenuation with the correction of side wall effect are about 1.4 times the theoretical values. Possible reasons for the difference between theoretical and experimental results are not clarified yet.

Motion of Bay Water Due to Incoming Tidal Waves

By Hikoji YAMADA

Studies on Oceanography dedicated to Prof. Hidaka in commemoration of his sixtieth birthday. Tokyo, 1964, pp. 350-358.

Abstract

The motion of bay water due to incoming tidal waves, *e.g.*, to tsunami, is studied by the Green's approximation to a canal of variable section area (H. Lamb's Hydrodynamics, 6th ed., 1932, p. 274), boundary conditions at the bay mouth being continuities of the water level and the quantity of flow. Bottom friction and mouth dissipation are considered simultaneously by two constants: The friction coefficient ε and the reflecting factor Δ of bay mouth. Bottom friction was assumed to be equal to $\kappa\rho|v|v$, where v is the sectional mean velocity of water, and to keep the governing equations linear $\kappa|v|2h$ where h is sectional depth is put equal to ε, which is assumed constant throughout the bay and is responsible for the bottom friction. The other constant Δ is the fractional wave height which returns into bay at the mouth when outgoing waves partially reflect there.

The energy extinctions by the bottom friction and by the mouth dissipation are compared by the relations $\mu=-\log\Delta$ and $\varepsilon\tau(2L)$, where $\tau(2L)$ is the time duration in which waves go and back the length L of bay, thus enabling us to decide the relative importance of either effect.

Taking these dissipations, into consideration movement of water level due to several types of incoming waves is calculated such as their development in time, their final oscillations if exist, and induced secondary undulations of the bay. The equations of motion can be solved, as are well known, either in a mode solution or in a ray solution, convenient one being employed as the case may be. If sine waves enter the mouth from the time $t=0$ on, the development of oscillations in bay is governed by two constantr $\varepsilon_1=\exp\{-\mu-\varepsilon\tau(2L)\}$ and ω_0/ω_1, where ω_0 and ω_1 are the circular frequencies of the incoming waves and the fundamental secondary undulation, respectively. The highest level occurs neither at first oscillation nor at last one in general; in resonance however, it occurs, at the last stationary oscillation and in anti-resonance at the first. Development of induced secondary undulations has also been studied, but not being clear if we can interprete the large proper oscillations of each bays on the occasions of tsunami.

Initial Movement of Bottom Sediment Particles and Generation of Sand Ripples Due to Wave Action

By Hideaki NODA and Takehisa IHO

Proc. 11th Conf. on Coastal Eng. in Japan, Nov., 1964, pp. 153-158.

Abstract

This paper are concerned with the initial movement due to wave action of sediment particles on a horizontal bottom, and generation of sand ripples.

In order to obtain the essential relationship between the initial movement of a sediment particle and wave characteristics, a theoretical consideration is made in the same manner as the theoretical treatment of critical tractive force in open channel by applying the theory of oscillatory laminear boundary layer on the bottom induced by wave motion. Laboratory experiments are also made to examine the velocity of the theoretical results.

Results of the theory indicate that the criterion for movement is expressed in terms of three dimensionless quantities: $u_0{}^{*2}/[(\sigma/\rho)-1]gd\tan\varphi$, the ratio of the maximum shear velocity to the maximum velocity of flow just outside of the boundary layer in the vicinity of a bed, $u_0{}^*/u_0$, and the Reynolds number with respect to the shear velocity and sediment size, $u_0{}^*d/\nu$. The experimental results show that quantitative prediction of initial movement by the theory is quite good when the value of $u_0{}^*d/\nu$ is less than about 20 and values of $u_0{}^*/u_0$ are 0.1 and 0.2 if the sheltering coefficient is assumed to be 0.4, and that the agreement of the theoretical value with the experimental one becomes poor gradually with increase in the value of $u_0{}^*d/\nu$ when $u_0{}^*d/\nu \gtrsim 20$.

In order to apply this theoretical result to practical problems in coastal engineering, the criterion for movement of sediment should be expressed by the critical depth of water for movement. Therefore, the dimensionless expression of the criterion in terms of $u_0{}^{*2}/[(\sigma/\rho)-1]gd\tan\varphi$, $u_0{}^*/u_0$ and $u_0{}^*d/\nu$ is replotted by factors including the critical depth of water, the wave characteristics and properties of sediment.

Results of the replot indicate that the ratio of critical depth to deep-water wave length, h_c/L_0 is concerned with three factors, d/H_0, H_0/sL_0 and βH_0, in which d is the diameter of sediment particles, s specific gravity of submerged sediments; H_0 deep-water wave height and β the quantity related to oscillatory boundary layer thickness.

The experiments for generation of sand ripples were made to obtain the relationship between the sediment size and wave characteristics under that condition. The experimental result shows that generation of sand ripples is also related to the dimensionless quantities, $u_0{}^{*2}/[(\sigma/\rho)-1]gd\tan\varphi$, $u_0{}^*d/\nu$, and $u_0{}^*/u_0$, in the same manner as for the initiation of motion.

An Experimental Research on the Subsidence of Ground (II)

By Sakuro MURAYAMA and Minoru MATSUO

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, March, 1964.

Abstract

In some cities and industrial areas developed on coastal alluvial plains, the ground subsidences caused by the pumping of enormous volumes of ground water are remarkable at present, and these phenomena have become the object of public attension in Japan.

The ground subsidences are mainly based on the consolidation of clay layers by the depression and the recovery of the artesian pressures in the adjoining aquifers, and a fundamental investigation under simplified conditions seems to be necessary to estimate them quantitatively or qualitatively. In this paper some results obtained by large scale model tests in the laboratory which have been performed in order to make clear the characteristics and the mechanism of ground subsidence are described. In a experiments two cylindrical soil tanks with a diameter of 2m and height of 1.5m in which clay and sand were put in alternate layers. The followings were measared ; (1) Measuring the variation of pore water pressure and settlement of the aquifers and the aquicludes caused by the following variations of the artesian pressure in the aquifers, viz. lowering, recovering or their repetating. (2) Measuring the variation of pore water pressure of the aquicludes by changing the surface water level.

Some test results are summarized as follows ; (1) The degree of consolidation versus time curves obtained from the distribution diagrams of pore water pressure in the clay layers do not coincide with those calculated by the basic formula of consolidation in which C_v is assumed as a constant. (2) In the tests under repetitionnl change of the artesian pressure in the aquifers, the clay layers are consolidated gradually with residual subsidences with increase in the number of repetitions and the greater the amount of change in the artesian pressure, the greater the total subsidences with the same number of repetition, while the sand layers show almost elastic behavior. (3) In the tests performed in order to investigate the effect of the depression of surface water level on subsidence, the measured distributions of pore water pressure in the clay layers are in considerably good agreement with those which are estimated theoretically.

On the Deformation Properties of Sands

By Sakuro MURAYAMA and Norio YAGI

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, March, 1964.

Abstract

The deformation properties of sands depend on many physical and mechanical factors i. e. shape of grain, grain size distribution, degree of saturation, void ratio, stress condition, rate of loading and history of stress and strain, etc. This paper is a report of some experiments and their examination of the relation between stress, strain and volumetric change with Toyoura standard sand which is particularly dense (void ratio : $0.57-0.64$), under various stress conditions in N. G. I. type triaxial apparatus. The saturated cylindrical specimens which had $8.0-8.5$cm height and 3.6cm diameter, were prepared. Stress conditions are as follows ; (1) mean principal stress σ_m is kept contant (σ_m-constant test), (2) isotropic compression test, (3) allround pressure σ_3 is kept constant (σ_3-constant test), (4) deviatoric stress $(\sigma_1-\sigma_3)$ is kept constant ($(\sigma_1-\sigma_3)$-constant test), (5) repetitional deviatoric stress is applied. Results of these tests are summarized in the following conclusions.

(1) In σ_m-constant test, if the void ratio of sand is the same, its stress-strain curve chiefly depends on $(\sigma_1-\sigma_3)/\sigma_m$.

(2) In σ_m-constant test, the relation between volumetric change $\Delta V/V$ and shearing strain γ is represented by a straight line on the logarithmic paper.

(3) In the isotropic compression test, the relation between volumetric change and isotropic pressure σ is not always linear on the logarithmic paper as proposed by Wilson & Sutton and Jakobson.

(4) Instead of the second term of following equation proposed by Skempton (1960) which represents the dilatancy effect of sand, a term expressed by $D^*(\sigma_1-\sigma_3/\sigma_m)$ seems to be fittable (where D^* ; coefficient).

$$\frac{\Delta V}{V}=C\Delta\sigma_m+\sqrt{2}D(\Delta\sigma_1-\Delta\sigma_3)$$

where C is the compression coefficient and D is the dilatancy coefficient.

(5) It was observed in the repetitional loading test that the effect of repetitional stress appears more remarkable if deviatoric stress $(\sigma_1-\sigma_3)$ become larger, i. e. that in the hysteresis loops, Young's moduli in final cycle (the state of residual strain$=0$) are 4 times those at smaller deviatoric stresses and 15 times those at larger ones in first cycle.

Influence of the Variation of the Intermediate Principal Stress on the Mechanical Properties of Clays

By Toru SHIBATA and Daizoo KARUBE

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, March, 1964.

Abstract

The results of an experimental study on deformations, pore-water pressures and shearing strengths of normally consolidated clays in three-dimensional stress space are presented. The undrained shearing tests of remoulded and reconsolidated clay in which intermediate principal stress can be controled (σ_2-variation tests) are performed.

The apparatus for "σ_2-variation test" consists of a triaxial compression apparatus with the part for loading intermediate principal stress. The size of specimen used in this apparatus is 6 cm high, 3.5 cm×2 cm cross-section. If major, intermediate and minor principal stresses are denoted by σ_1, σ_2 and σ_3 respectively, stress conditions during tests are given by:

1st step : consolidation under hydrostatic pressure; $\sigma_1=\sigma_2=\sigma_3$,

2nd step: $\sigma_1=\sigma_2$ increased till they reachs a certain value, while σ_3 is kept constant (under undrained condition),

3rd step: σ_1 only increased till failure occured, while $\sigma_2\neq\sigma_3$ kept constant independently (under undrained condition).

The major principal stress is increased at a constant strain rate of 0.01% per minute of specimen hight, and the pore-water pressure during shear is measured at the bottom of the specimen.

(1) Pore-water pressure during shear is given by the applied mean principal stress ($[1/3]\cdot[\sigma_1+\sigma_2+\sigma_3]$) and shearing stress ($[1/3]\cdot[\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}]$, but seems independent of the direction of the shearing stress. In other words, the relative of the intamediate principal stress does not seem to affect the dilatancy effect.

(2) The failure strain in the direction of major principal stress decreases with the increasing value of (σ_2/σ_3). For example, failure strain is about 10% for the ordinary compression tests $(\sigma_2/\sigma_3=1)$, while it is about 5% for the test of $(\sigma_2/\sigma_3)=1.6$. But, if the failure strain is defined by $\gamma=(1/3)(\sqrt{(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2+(\varepsilon_3-\varepsilon_1)^2})$, different results will be obtained.

(3) The actual failure surface for clay is a curved surface which circumscribes the Mohr-Coulomb hexagon, hence the difference is on safe side if our estimates of the safety factor are based on the conventional triaxial test results.

Salt Balance in Kojima Lake (Part 2)

—Effect of Sea Water Leakage on Salinity Distribution, Sweeping away of Salt by Flood and Salt Diffusion in Bottom Soil—

By Setsuo Okuda

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 290–298.

Abstract

Some dominant factors controlling the salt balance were investigated for predicting the final state of salinity distribution in Kojima Lake (which was formed by closing the bay mouth to exchange the sea water for river water). This means that we formed the bay in this way if it happened naturally—"Kojima Lake which was formed by the mouth of the bay closing, thus substituting rwer water for sea water".

Important results on the bases of field observation and quantitative analysis were obtained as follows.

(i) Estimation of salt inflow by a leakage of sea water.

The inflow rate of salt by a leakage of sea water through the sluices and dyke was estimated by a direct measurement with current meter and an indirect calculation from the change in the salinity distribution, and its value seemed to exceed 3×10^8 tons per day.

The observations of current and salinity show that the sea water flows into the lake with high speed through a few large cracks under the sluice gates during high tides, but it creeps along the bottom surface and sinks in the lower part of if this a single known hollow near the dyke owing to its heavier weight and does not directly cause the salinity increase in the surface layer.

(ii) Sweep away of salt water by flood inflow of river water.

During an ordinary river inflow, heavier salt water stays in the lake under a stable interface between upper fresh and lower salt waters.

A severely turbulent and rapid flow of river water at the stage of flood inflow after heavy rainfall can, however, sweep away the lower salt water for a short period.

Comparisons between the salinity distribution before and after the flood with various inflow rates show that a flood with a larger flow rate than $70m^3/sec$ sweeps away the salt water from the lake almost completely.

(iii) Salt diffusion in bottom soil.

Salinity distribution in the lake can be affected by the salt being released from the bottom and the release rate depends on the diffusion of salt in the bottom soil.

The salinity distribution was analytically investigated on the basis of the diffusion equation in which the diffusion coefficient decreases exponentially with depth and its results were compared with flume experiment and field observation.

It seems that, the diffusion coefficient at the bottom surface in Kojima Lake

is about 10^{-3} cm^2/sec and larger than that of other places since there exists a remakable movement of ground water.

On the Deviation from Knudsen's Formula of the Density of Sea Water and its Bearing on the Productivity of the Sea

By Yoshiaki FUKUO

Memoirs of the College of Science, University of Kyoto, Series A,
Vol. XXX, No. 3, Article 1, March, 1964, pp. 273-321.

Abstract

In oceanography, the salinity and density of sea water are usually obtained from Knudsen Tables by chlorinity titration. This method is based on the fact that the relative composition of major constituents in sea water is quite uniform. In coastal areas, however, it may be said that the uniformity of the relative composition is impaired by the addition of materials due to the influx of land water and the absorption of materials due to biological production.

This author measured th density σ_0 of coastal water by Knudsen's method and the actual density σ_0' of the same water by a newly constructed hydrometer (accuracy within $\pm 3\times10^{-6}$) at the same time, and calculated the difference $\Delta\sigma_0 \equiv \sigma_0 - \sigma_0'$ between these two densities, which was termed "salinity deficit",

The exchange of water in Akashi Straits and Tanabe Bay was discussed with reference to the correlation diagram between the chlorinity and salinity deficit, and then it was found that the salinity deficit was a valuable index for water mass analysis and was closely related to the stagnation of sea water.

Furthermore, considering the factors influencing the variations of the salinity deficit and biological production, two equations were derived under various assumptions. These equations were regarded as the simultaneous differential equations between the plankton population and the salinity deficit. The coefficients in these simultaneous differential equations were calculated by the method of least squares in every month, using the values of tidal range, chlorinity, salinity deficit and plankton population which were observed in Tanabe Bay from July, 1958 to July, 1959. These simultaneous equations were solved numerically concerning the plankton population and salinity deficit by Runge- Kutta's method using the calculated coefficients. The result of numerical calculation agreed fairly well with observed variation.

The differential equation of only the plankton population, which was often seem in the theory of vibration, was obtained by eliminating the salinity deficit in the simultaneous differential equations. It was found that this defferential equation had an unstable solution in November, 1958 and February, 1959 when the abrupt blooming of plankton population occurred and that the mode of oscillation on the right-hand side of this equation, which corresponds

to external force, was roughly similar to the variation of plankton population.

Finally, the production in Tanabe Bay was estimated from the increasing rate of salinity deficit proportional to the plankton population.

On the Exchange of Water Through the Tidal Current

By Yoshiaki FUKUO

Bulletin on Coasted Oceanography, Vol. 3, No. 1, June, 1964, pp. 27–32.

Abstract

The mixing of water in coastal areas has been recently emphasized as a serious problem in connection with the maintenance of biological productivity, the disposal of waste pollution and the reconstruction of coastal zones. In general, the mixing process is too complicated for purely theoretical treatment owing to the influences of the regional characters of tidal motion, wind and wave actions and topographic effects, and therefore field surveys of the salinity distribution or the diffusion of tracer such as dye and radioactive isotope are a great help in estimating the degree of mixing. But, for the extimation of salinity, knowledge of the effective influx of fresh water is necessary and the use of tracer requirs a careful examination of back ground.

The Chlorine-ratio of coastal water is varied by the addition of materials due to the inflow of land water and the absorption of materials due to biological production. The fluctuation of its ratio can be reduced to the deviation of actual water density from sea water density given by Knudsen's Tables. This deviation, which is tentatively termed "salinity deficit", is both carried away by the crrent and is diffused by mixing. The author pointed out that the salinity deficit was accepted as a valuable index for the mixing process, that is, the water type was analysed successfully by the correlation diagrams between the chlorinity and salinity deficit obtained from the investigations.

Referring to these diagrams, it was shown that, in Akashi Straits, the exchange rate was about 10 % of the tidal volume of water every half period of a tidal current and that the central part of Tanabe Bay and an inlet of Ago Bay, where a large circulating current was observed and the cultivation of pearls seemed to be above average, had relatively higher values of salinity deficit and the degree of mixing was closely related to the salinity deficit because the salinity deficit increased or decreased according to the consumption or replenishment of salts in the sea water respectively.

On the Infiltration and Runoff of Snow-melt Water

By Yoshiaki FUKUO and Kazuo OKUNISHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 294-240.

Abstract

An investigation on the infiltration and runoff of snow-melt water was carried out in the Kuzuryu River Basin from March through May 1963.

At first, the flow of snow-melt water occurring at the surface of the snowpack was traced with fuchsine. Downward velocity of the flow through horizontal snowpack was 32 cm/hr in the daytime, and the velocity of the flow along the granular ice layer at a slope (inclination 20°) was 3~30 cm/hr varying with depth.

Simultaneously, the distribution of underground temperature was observed every hour. Analysis of heat balance gives the value of the infiltration rate of 7.2×10^{-5} cm/sec, which was roughly foreseen fron the soil moisture measurement.

Groundwater level at a flat place, the level and quality of the river water at four stations, and meteorological data were obtained through out the period of investigation. A good correlation was found between the river water level and the concentration of electrolite.

The river water level and the groundwater level showed the same diurnal variation in the upstream region, and the time lag between thawing and river discharge was about 12 hours in March and decreased later. Correlation between the thickness of snowpack and the time of minimum groundwater level revealed that about 30 cm decreasa of the former quickened the latter by one hour, which is consistent with the downward flow velocity of snow-melt water in the snowpack. Thus the time lag of 12 hours between thawing and runoff may be explained as follows: The snowpack takes 5~7 hours to reach the ground surface. and further the storage effect of groundwater delays the phase of its fluctuation by 6 hours (1/4 period of diurnal variation).

It is concluded that the mechanism of runoff of the snow-melt water was essentially identical with that of groundwater discharge, because of the warm climate of the basin throughout the investigation period.

On the Observation of Ground-Strain and Ground-Tilt at a Landslide Zone (II)

By Michiro TAKADA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, 1964.

Abstract

At Kamenose Landslide area located in Toge, Kashiwara City, Osaka Prefecture, a geophysical investigation and observation to establish the perfect stabilization plan was begun at the end of 1962.

a) Seismic prespecting

For the purpose of studying the crustal structure in this area, seismic prospecting was carried out along the same traverse lines late in March, 1963 (the dry season) and early in July (the wet season). As the crustal structure in this area, the upper most zone (0~15 m in thicknes) was a layer of clay with pebble of which the propagation velocity of P-wave was 0.4~0.6 km/s. The next zone was the cataclasite layer with 2.4~2.7 km/s and the fractured zone with 1.2~1.6 km/s was caught in this layer.

b) The sliding movement survey and the observation of tilting motion on the ground surface

The observation of ground-strain is being carried out by 18 extensometers (wire type, self-recording system) set up along a survey line and the observation of ground-tilt is being carried out by 2 tiltmeters set up on the survey line and a tiltmeter (horizontal pendulum type, self-recording system) set up on the opposit side of Yamato-gawa. From the results of these observations, the variation and distribution etc. of ground-strain (distribution of the compressive zone and tensile zone) were found. The ground deformation was affected by rainfall. It was ascertained that on the part which the change caused by rainfall was extension, the secular variation was extension and the contrary was true when the change caused by rainfall was contraction, as was also the secular variation. This landslide area was also divided into two blocks by the fractured zone, i.e. the higher block above the fracture zone and the lower block below the fractured zone.

c) The observation of underground deformation

For the purpose of finding the depth of slip surface, the observation of underground inclinometer which was manufactured to be tested here. It was found that the slip surface almost coincided with the boundary surface (10~15 m in depth) of the first layer and the second layer and the first layer (0.4~0.6 km/s) was sliding.

Moreover the observation of groundwater level is being carried out.

From the results of those investigations and observations the outline on the landslide in this area was found.

On the Landslide Mechanism of the Tertiary Type Landslide in the Thaw Time

By Yūji TAKADA

Bulletin of the Disaster Prevention Research Institute, Kyoto University
Vol. 14, Part 1, August, 1964, pp. 11–22.

Abstract

Landslide phenomena can be divided geologically into the three following types,

1) The landslide occurring in the tertiary formation zone (tertiary type landslide)
2) The landslide occurring in the crushing zone (hasaitai type landslide)
3) The landslide occurring in the hot spring zone (onsen type landslide)

Among them, the tertiary type landslide is the most impressive type in regard to scale and number. Compared with the other types, this maintains a certain general character in the phenomena. Therefore, it is comparatively easy to discover the law of the predominant phenomena of this occurrence.

The landslide which is considered as a tertiary type at Tsukiike, Matsunoyama, Higashikubeki-gun, Niigata Pref., was selected for our observation. The motion of this landslide is very active, the displacement being about 6 meters a year. Hence the mechanism of this landslide can be studied in a short period of observation.

In order to investigate the mechanism of the underground soil displacement stage, internal strain meters and soil pressure meters were set at 8 stations. The soil pressures and strain measurements were carried out every 3rd day on an average.

The results of measurements taken by internal strain meter and soil pressure meter show that the soil block moves gradually from the upper part of the landslide area to the lower. The depth where the displacement occures is different at each station, viz, at some stations the deepest zone moves and at some the "tunnel movement of soil" occures. When the displacement of landslide is maximum in each station, the displacement is at its maximum, as a rule, at the surface zone in which the depth from the soil surface to bed rock is shallow, but in the place where that depth is deep, the "tunnel movement of soil" is conspicuous. At the terminal part of the active landslide area, the same displacement velocity is observed from the upper zone to the lower of the slide layer. By observing the slide zone in the slide layer at one station during a fairly long period, an interesting phenomenon is observed that the slide zone does not exist always in the same place, also occures in other places too.

On the Design Wind Force of Steel Stacks

Yoshitsura YOKOO and Hatsuo ISHIZAKI

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 14, Part 1, August, 1964, pp. 47–53.

Abstract

It is well known now that the vibrations of stacks are mainly caused perpendicular to the wind direction, but research on this problem had not been made until ten or twenty years ago. After the war, many all-welded tall steel stacks were constructed and some of them were partially damaged by the violent vibrations induced by wind. A number of papers on this problem have been published recently and there is now more data about it, although this phenomenon has not yet been completely clarified. In this paper, the wind resistant design of welded steel stacks discussed referring to studies in this country and abroad.

First considered were the vibrational characteristics or the natural frequencies and the logarithmic decrements of actual stacks and the models that were obtained by experiments. Also the Strouhal numbers and the lateral forces resulting from the vortex shedding were considered in order to find out the wind forces applied to the stacks. To fix the resonant wind velocities for design, usual Strouhal numbers should be used. It is difficult to determine seperately the values of the magnification factors and lateral forces due to the resonant vibration, so it was proposed that the magnification factor and the lateral coefficients should be combined together into a single factor. This factor will be influenced by the figure, the weight, the rigidity and the damping character of the stack. A conventional way from our experience for designing steel stacks is to consider the values of this factor as proportional to the slenderness of a stack. The values are shown for self-supported and all welded large stacks. The problems on the buffeting, the ovalling vibration and the wind force reduction by some devices are not included in this repart.

Vertical Gusts near Surface in High Winds

By Yasushi MITSUTA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 199–206.

Abstract

Three dimentional wind components at 10 m from the ground in typhoon winds are studied by the use of a propeller anemometer and a specially designed all-weather type bivane, whose free period is about 15/V sec (where V is in m/sec) and damping ratio is 0.15, at the Shinomisaki Wind Observatory of Kyoto University.

The data used in this study was obtained on Aug. 28, 1963 when Typhoon 6311 was passing over the southern ocean at Shionomisaki. The mean wind speed at 10 m over the sampling duration (6 min) was 18.3 m/sec. The vertical fluctuating components are smaller than the longitudinal ones, and they decrease more rapidly at average time. Their ratio is about 20-30% for a few second average winds but it becomes nearly 10% for 20 or 30 sec winds. And the correlational coefficient between longitudinal and vertical components is about −0.7. The main characteristics of the observed fluctuating components are shown as follows (in m/sec unit) ;

Averaging Time	Extreme Value			Standard Deviation			Correlation Coeffcient		
sec	u′	v′	w′	u′	v′	w′	Ru′v′	Ru′w′	Rv′w′
3	11.0	7.2	3.3	4.43	2.21	0.87	+0.13	−0.62	−0.19
6	10.6	4.6	2.1	4.20	1.80	0.69	+0.27	−0.70	−0.28
12	10.0	2.8	1.2	3.77	1.28	0.50	+0.41	−0.74	−0.39
24	4.8	1.9	0.7	2.69	1.00	0.31	+0.31	−0.82	−0.13

Anemometers of Shionomisaki Wind Observatory

By Ryo TANABASHI, Hatsuo ISHIZAKI and Yasushi MITSUTA

Annuals, Disaster Prevention Research Institute Kyoto, University,
No. 7, March, 1964, No. 7, pp. 207-217.

Abstract

The Shionomisaki Wind Observatory of the Disaster Prevention Research Institute of Kyoto University was established in 1961 for the purpose of advancing the study on the mechanism of wind disasters on structures, by means of fields experiments with full scale structures in natural winds. Observations of the nature of storm gusts, wind forces on structures and the response of the structures of the wind forces are the main activities of this observatory. This is the first observatory which is specialized in wind studies in Japan and perhaps in the world. It is placed in the southern end of the Honsyu Island where typhoon winds are expected very frequently.

Various kinds of anemometers are used or under developing in this observatory to perform the special purposes of the study. They are divided into three main groups. The first group consists of instruments for the study of long range wind variations and their climatological comparisons. Most of them are the same as the ones used in other meteorological observatories, except an all weather type bivane which is used with the propeller anemometer to measure three dimentional wind fluctuations, and which was specially designed in this observatory. Its free period is 15/V sec and its damping ratio being 0.15. The second group is the instruments for the short period fluctuation measurements. Anemometers of this kind are the most important for the studies of wind effects on structures and should be able to resolve fluctuations

up to 10 cps. Two kinds of new anemometers are specially designed for this purpose. One is pressure plate type and the other is pressure tube type. And both of them have electrical transducers. 15 sensors of these are used to study spacial distribution of storm gusts. A sonic anemometer is also under developing to resolve very high frequency changes. The last group of anemometers is for the study of the topographic modifications wind systems. They are designed to be easy in handling and removing.

A Meteorological Study on Snow Melting

By Ryozaburo YAMAMOTO, Ken SAHASHI, Yasushi MITSUTA and Mitsuo MIZUMA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 7, March, 1964, pp. 218–228.

Abstract

Micrometeorological observations are carried out in the air layer near snow surface during 7 days in the middle of March 1963, a period of snow melting, and every components of the thermal balance on the snow surface are estimated. The results show that the heat flux required for snow melting is nearly at balance with the net radiative flux during the observation period as shown in the Table, although it is suggested that the contribution from the sensible heat flux will probably become appreciable during the best season of snow melting as a result of the air temperature resing. A climatological formula for predicting the snow melting rate is derived, basing upon some physical reasonings. The usual meteorological data, such as daily income of short-wave radiation, wind speed and the air temperature are available for this formula, that is,

Components of thermal balance on snow surface.
S+L+V+M (cal cm^{-2})

Data	Time	S	L	V	M
		Not radiative heat flux	Sensible heat flux	Latent heat flux	Heat flux requried for snow melting
17	Day Time 07–17^h	79	−8	32	103
	Night Time {00–07^h, 17–24^h}	−21	1	6	−14
18	Day Time	140	7	−5	142
	Night Time	−58	29	13	−16
19	Day Time	184	31	−8	207
	Night Time	−66	16	13	−37
20	Day Time	210	47	2	259
	Night Time	−62	48	55	41

$$\Delta z = \frac{1}{32}(0.50S_d + 6.9\times10^{-2}K_a\theta_{as} - 50),$$

where Δz is daily snow depth decrement in cm, S_d is daily income of short-wave radiation per unit area (Cal $cm^{-2}\,day^{-1}$), K_a is eddy conductivity of the air ($=ku_*z$, k; Karman constant, u_*; shearing velocity, z; height) which is estimated from wind speed and has the order of 10^2-10^3 and θ_{as} is the air temperature in °C. The agreement of the formula and observed daily snow depth is tolerable in so far as the data at our observed point.

On the Sonic Anemometer

By Yasushi MITSUTA and Mitsuo MIZUMA

Tenki (Meteorological Society of Japan), Vol. 11, No. 2, Feb. 1964, pp. 33-40.

Abstract

A brief review of the theory and history of the sonic anemometer, which is a new and promissing instrument in the field study of meterology, is presented in the first part of this paper. The sonic anemometer has several advantages which none of the traditional anemometers has had, the essential one being absence of moving part in it that makes possible to reduce the lag of the instrument considerably and to attain wide measurable ranges from gentle breeze to strong gale. The basic principle of this instrument is that the apparent propagation velocity of sound waves is altered by the movement of its medium, so we can measure wind velocity by detecting this deviation of sound propagation caused by wind.

Carrier and Carlson (1944) are the first persons who attempted to make a sonic anemometer. Wind speed was obtained by measuring the phase difference between the signals recieved by the two microphones located upwind and downwind, respectively, from a continuous source of sound. But the instrument was never completed. Suomi (1946) also made an experimental apparatus in sing-around method. Since then, Corby (1950), Schotland (1955), Suomi (1957), Bovsheverov and Voronov (1960), Gurvich (1960), John (1960), Kaimal (1962) and Kaimal and Businger (1963) have described their own sonic anemometers in various method and physical dimentions.

In the second part, a new sonic anemometer developed by the present authors is described. In this instrument wind speed is obtained by measuring the difference of the traveling time of two series of sound pulses transmitted in the opposit directions along a fixed sound path, which is almost the same way as that of Suomi (1957). Ultrasonic wave of 80 kc is used to make 200 pulses per second for measurment. The length of the sound path is 120 cm. Four barium titanic acid oscillating elements are used for transmitters and recievers at their resonant point. The wind speed out put is obtained as the length of the sweep on the oscilloscope. Field tests indicates this instrument performs satisfactorily

On the Characteristic of the Oscillation of Water Level in Nagoya Harbor (Continued)

By Haruo HIGUCHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 400–409.

Abstract

For examining the frequency response of the oscillation of water level in a harbor, which has narrow openings, a series of hydraulic experiments were carried out in two models of Nagoya Harbor, which had been used for model experiments on tidal currents.

One is the small model, of which the horizontal scale is 1/2000, the vertical one is 1/667, and the dimension is about 5×11 m, and the other is the large model, 1/700, 1/500, and 25×33 m respectively. Many kinds of sinusoidal waves were provided to these models which had some varieties in the widths of the openings, the water surface area, and the water depth, and the time history of water levels in the harbor were observed.

Through these experiments it was clarified that:

1) The shorter the period of the incident waves, the narrower the width of the opening is, the larger the water surface area in the harbor is, and the shallower the water is, the more the reduction of amplitude and the increase in phase lag are remarkable in the harbor.

2) With respect to the phase lag, the phase lag of high water is generally larger than that of low water, so that the waves were deformed, and the difference in the phase lag between high water and low increases with the increase in the phase lag. The experimental value of the phase lag is generally larger than the theoretical one, which is calculated by assuming long waves.

3) The reduction of amplitude in the harbor is affected by the amplitude itself even though the period is the same, that is, the so-called non-linear effect appears. The larger the amplitude the more remarkable the reduction is. The shorter the period the narrower the opening the larger the water surface area in the harbor and the shallower the water the more remarkable the non-linear effect is.

4) The phase lag in the harbor is also affected by the amplitude, but the tendency is not simple as in the reduction of amplitude and it seems to depend on the period and water surface area.

5) The period of natural oscillation in the model is approximately as long as 1.5 times of theoretical value, which is calculated by assuming long waves.

6) The experimental values of responese factor and phase lag coincide qualitatively with the theoretical values derived by Rovert W. Love with a simplified model.

On Observation of Tidal Currents at Nagoya Harbor

By Haruo HIGUCHI and Shigehisa NAKAMURA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 410-419.

Abstract

An observation of currents was carried out at Nagoya Harbor on 23 and 24 July, 1963. The depths of the stations were about 7 m. The tidal phases of this observation were flood tide and ebb tide at Spring tide. Currents, water temperatures, chlorinities and bottom sediments were observed and sampled by three types of current meters, a Nansen's water sampler, and a sediment sampler. Vertical distributions of current velocities were obtained both at flood tide and at ebb tide.

The currents at the stations were considered to be mainly tidal currents and affected partly by the inflow of river water and wind stress near the sea surface. The maximum velocity of observed currents was about 15 cm/sec. The profiles of current velocities are complex and the maxima of current velocities are found near the sea bed. Vertical distributions of chlorinities and water temperatures suggest that the inflow of river water is one of the factors which affects the profiles of current velocities in each case.

Referring to the observed data of tidal currents, bottom stresses and coefficients of vertical eddy viscosity were estimated.

Bottom sediments at the stations consisted of silt and clay. But it is difficult to distinguish between smooth and rough sea bed so that the friction forces at the sea bed are estimated in the case of smooth and rough surfaces under the assumption that current velocity profiles near the sea bed hold the logarithmic law, i. e., von Karman's formula and Prandtl's formula respectively. Calculated values of the friction force at the sea bed vary within the range of 0.043 to 2.60 dyne/cm^2. The frictin coefficient is about 2×10^{-3} for smooth sea bottom.

The coefficient of vertical eddy viscosity is calculated under the assumption that the energy of eddy viscosity is supplied by the turbulence energy of currents, i. e., $f=\frac{1}{2}\rho(\delta u)^2$ equals to $\eta\frac{\partial u}{\partial z}$ where δu is the turbulence component of currents or the difference of current velocities in a distance of δz, ρ is the density of water, $\frac{\partial u}{\partial z}$ is the vertical gradient of velocity, and η is the coefficient of vertical eddy viscosity. The calculated values of η are within the range of 10 to 10^3 and the maxima of η are found near the sea surface and about 5 m below the sea surface.

On Wave Observations at Nagoya Harbor and Izumisano Coast

By Haruo HIGUCHI, Yoshito TSUCHIYA and Tadao KAKINUMA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 420-433.

Abstract

Forecasting shallow water ocean waves is one of the most important problems in coastal engineering at present. Nevertheless, among the characteristics of shallow water ocean waves, the wave height reduction due to bottom friction is not well known.

To make clear the transformation of shallow water ocean waves, wave observations were made at Nagoya Harbor and at Izumisano Coast in 1962 and 1963 respectively.

This paper presents the facilities and equipments used, the methods of wave observations analyzed by both the significant wave method and the wave spectrum method.

At Nagoya Harbor, two step resistance type wave recorders were installed at depths of 9.2 m and 5.0 m and the corresponding wind data were obtained. At Izumisano Coast, the bottom sediments were sampled, three buoys were set along the direction of wave propagation at depths of 6.0 m, 4.0 m and 3.4 m respectively, and the three buoys in wave motion were photographed simultaneously for about seven minutes by using a 16 mm camera with a 1000mm-f : 6.3 telephoto lens.

At Nagaya Harbor, wave data could not be obtained at the corresponding two stations offshoreside and onshoreside, only three wave data being obtained for the low-wind waves at a short fetch and for a short duration. This wave data is compared with the theoretical values obtained by Longuet-Higgins (1952). It is found that the ratios of various mean wave heights estimated are somewhat larger for a deep water wave and smaller for a shallow water wave than the theoretical estimates.

At Izumisano Coast, two wave data could be obtained at the corresponding two stations offshoreside and onshoreside. From these data are obtained the transformations of ocean wave spectra in shallow water which are very important in clarifying the energy transmission in shallow water. All the wave data at Izumisano Coast is also compared with the theoretical values obtained by Longuet-Higgins (1952), and the same tendency as at Nagoya Harbor is found.

On the Friction of the Sea Bed and the Coefficient of Vertical Eddy Viscosity Associated with Tidal Currents at the Opening of a Break Water

by Shigehisa NAKAMURA

Proc. 11th Conf. Coastal Eng. in Japan, Nov., 1964, pp. 94-97.

Abstract

A break water at Nagoya Harbor which has two openings, was for the most post constructed at the beginning of 1964. The main opening is for open-sea vessels (about 10 m of water depth) and the subopening for ships of fisheries (about 7 m of water depth). Tidal currents in the cross section of the openings have been observed by the 5 th Harbor Construction Bureau, Ministry of Transportation from January to February 1964. The observations were carried out both at the ebb tide and the flood tide. It was spring tide at the time of observations when the sea surface was rather calm.

Friction force on the sea bed and the coefficient of vertical eddy viscosity are calculated from the data of tidal currents.

To calculate the friction of sea bed, vertical velocity profiles of tidal currents near the sea bed are assumed to be logarithmic and the data of currents at 1 m above the sea bed are used. The bottoms at the openings are assumed to be smooth surface. The maximum value of the friction force on the sea bed was 4.2 dyne/cm^2 in average.

The results show that the friction of sea bed increases with an increase in the tidal current velocity at 1 m above the sea bed. A trend is found that the friction of the sea bed decreases with the increase in water depth. The friction coefficient of the sea bed is about 2×10^{-3} on average for the smooth bed which varies with time or with current velocity within the range of 1.5 to 2.2×10^{-3}. The tidal phase of a maximum friction corresponds to that of a minimum friction coefficient of the sea bed.

The coefficient of vertical eddy viscosity is calculated under the assumption that the energy of eddy viscosity is supplied by the turbulence energy of currents, i.e., $f=(1/2)\,\rho\,(\delta u)^2$ equals $\eta\partial u/\partial z$ where δu is the turbulence component of currents or the difference between current velocities within a distance of δz, ρ is the density of water, η is the vertical eddy viscosity. From this calculation, areal means of η in the cross sections of the two openings are obtained, which are in the range of 100 to 800 and seem to vary with the tidal phase in a confused relation.

The Effect of Secondary Flow on Curved Flow

By Yoshio MURAMOTO and Shinichi ISHIDA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 315-328.

Abstract

This paper describes the hydraulic characteristics of the upper layer and the lower in a fully developed region of curved flows which have secondary flows in radial direction.

As for the upper layer unaffected by the bed shear stress, the effects of secondary flow on a main flow are examined on the basis of Eulerian equations of motion and continuity in cylindrical coordinate system. In comparison with the behaviours of the curved flow based on free vortex theory, it is illustrated that the secondary flow has an influence upon the main flow in shifting the higher velocity filament toward the outer bank and in increasing the superelevation of the water surface.

The velocity distribution of the main flow and free surface profiles are determined by the use of the following assumption instead of boudary conditions, that, "in one cross section of curved flows, the mean depth coincides with the depth at centerline radius." General properties of tangential velocity distribution and free surface profiles with increase of centerline radius are discussed in detail. Further, several experimental results in the fully developed region of circular curved channels indicate good agreement with the present theoretical velocity and surface profiles except near the side walls.

On the other hand, in order to determine the behaviour of the lower layer, two analytical approaches under the condition of laminar flows are presented. One approach determines the lower layer thickness based on an equation of continuity between two layers, and the other determines the lower layer thickness, the position and the value of the maximum radial velocity by the use of the equation of continuity and equations of momentum for the radial and the tangential direction. At the boundary between two layers, the boundary conditions adopted in these approaches, different from those of previous studies, are that the radial velocity and its vertical gradient in the lower layer are equal respectively to those in the upper layer. Although these approches intend to analyze the laminar lower layer, similar theoretical procedures may be applied for the turbulent lower layer under assumptions of exponential velocity distributions and bed shear stresses in radial and tangential direction.

Direct Measurement of Wall Shear

—Studies on Flow with Very Mild Hydraulic Gradient (2)—

By Shoitiro YOKOSHI and Mutsumi KADOYA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 7, March, 1964, pp. 311-314.

Abstract

Rigid wall shear is the most significant resistance in an open channel flow and has great effect both on the structure of a flow and on the wall of a channel. Preston's method used in an open channel water flow is unsuitable for the measurement of a low intensity of the wall shear and that on a rough wall. The high sensitive device suited to the measurement of a bottom shear of an open channel is developed by means of a direct balance measurement.

The device is based on the principle of a simple pendulum. The sensing element is a $15\times6\,cm^2$ flat drag plate suspended by four nylon threads in water and so arranged that a part of a channel floor of the measuring point is exactly replaced by the plate. Flow is not disturbed by the measurements since all the mechanisms are kept in a box mounted under the channel floor. The displacement of the drag plate due to the wall shear is measured by a water proofed differential transformer and recorded by an electronic self-balancing recorder. The device has many advantages as follows. The low intensity of the wall shear is measurable because the device has no mechnical frictions at the displacement of the drag plate: 0.01 dyn/cm² wall shear ($u_*=$ 0.1 cm/sec) can be well measured. The sensitivity is adjustable within a wide range with the change of the weight of the drag plate. A complete linearity exsists between the wall shear, the displacement of the drag plate and the output voltage of the differential transformer. The static characteristics mainly used are $\tau_W=9.20x$, where τ_W (dyn/cm²) is the wall shear and x(cm) the displacement of the drag plate. In this sensitivity, the device has the proper period 3.21 sec and damping ratio 1.80. Weak points of the device are that the measurement is restricted to the bottom of the channel alone and the size of the drag plate is ratter large.

Some measurements are made in a rectangular steel channel 50 cm wide and 40 m long. Estimation of Karman's constant on a smooth bed gives a value of approximately 0.4. Preliminary experiments to reveal the law of the resistance in the flow of a very hydraulic gradient are made and sufficient results are obtained.

Obituary Notice of Professor Susumu TOMOTIKA

Late Professor Susumu Tomotika

Professor Susumu Tomotika, a fellow of the Disaster Prevention Research Institute, professor of physics in the University of Kyoto, passed away on December 9th, 1964, in his sixty-first year. By his death we have lost one of the most distinguished leaders in fluid mechanics and also in this institute in particular.

Born on April 11th, 1903, at Matsuyama, Ehime Prefecture, Professor Tomotika graduated the course of physics in the Faculty of Science, the Tokyo Imperial University in 1926. Immediately he was appointed an assistant in the same university and in 1929 he was promoted to an assistant professor. In 1932 he took the degree of D. Sc. at the Tokyo Imperial University and in 1933 he moved to the Osaka Imperial University. Since 1934 to 1936 he visited England, Germany and Italy as an overseas scholar of the Ministry of Education, and he stayed in Cambridge for fourteen months and engaged in research of fluid mechanics under the guidance of Professor G. I. Taylor (Sir Geoffrey Taylor). On coming home he was promoted to a professor of the Osaka Imperial University and in 1943 he moved to the Kyoto Imperial University (the University of Kyoto), which position he held up to the time of his decease. Since 1953 he has been a fellow of the Disaster Prevention Research Institute.

The research activity of Professor Tomotika covers almost all branches of modern fluid mechanics and also the related subjects such as the theory of elasticity and acoustics. In the earlier stage of his research career he was interested in aerodynamics and a great deal of works was done by himself and his younger colleagues under his guidance on the wall effect of the flows of an incompressible perfect fluid. These works resulted in various important practical applications relating to the ground-effect of the aeroplane performance and the similar problem of the model plane in the wind tunnel.

During his stay in Cambridge Professor Tomotika participated in joint work on turbulence guided by Professor Taylor, whose unique personality and unparalleled originality in work gave him deep and everlasting influence. In this period his work was mostly concerned with the dynamics of viscous fluid, in particular, the laminar boundary layer, the hydrodynamical stability, and the generation and structure of turbulent flow.

The progress in the aircraft engineering stimulated the construction of the high-speed aerodynamics, and Professor Tomotika was one of the earliest

workers on the flows of compressible fluid. Among many works carried out in his laboratory we should mention his joint work with Professor K. Tamada on the transonic flow, which is an unique achievement under the severe condition of this country just after the war and was highly appreciated by scholars abroard.

The latest stage of research work of Professor Tomotika roughly coincides with the period in which he has been a fellow of this institute. In this stage his interest was concerned with geophysical problems in fluid mechanics. The works carried out under his directional influence in this institute and elsewhere covers the following wide spectrum of subjects: flows in porous media, boundary layer in density flows, thermal convection in various flows, micro and macro phenomena in meteorology, the theory of turbulence, and magneto-fluid dynamics in general.

The administrative activity of Professor Tomotika is by no means less eminent than academic one. Within the university, he was nominated three times a member of the University Council (1952-4, 1959-61, 1962-4), served as the dean of the Faculty of Science (1959-61), and appointed concurrently a member of various institutions in the university. Out of the university, he was elected a member of the Japan Science Council (1951-4), the director of the Physical Society of Japan (1958-9), the chairman of the Committee for Mechanical Research in the Science Council (1961—), a delegate to the International Union of Theoretical and Applied Mechanics (1963), and a member of the Organizing Committee of the International Congress of Applied Mechanics (1963—).

In recognition of his outstanding contributions to science, a Second Order of Merit was conferred on him on December 9th, 1964.

He is survived by his wife and two sons.

(T. Tatsumi)

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